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OXYGEN DEPLETION UNDER ICE COVER
IN THE RED DEER RIVER

BY

(C) JOHN TREVOR CHAPMAN

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF CIVIL ENGINEERING

EDMONTON, ALBERTA
FALL, 1972

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UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Oxygen Depletion under Ice Cover in the Red Deer River" submitted by John Trevor Chapman in partial fulfillment of the requirements for the degree of Master of Science.

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Oxygen Depletion under Ice Cover in the Red Deer River" submitted by Jens Trevor [illegible] in partial fulfillment of the requirements for the degree of Master of Science.

ABSTRACT

During past winters the Red Deer River has suffered from low dissolved oxygen concentrations downstream of the City of Red Deer. The cause of the oxygen depletion has primarily been the effluent from the City of Red Deer Sewage Treatment Plant.

During the winter of 1971-72 a survey to determine the effects of operation of the U-tube aerator at Joffre Bridge was begun, and was later modified to a limited analysis of the oxygen depletion in the 50 miles of river downstream of the City of Red Deer. During the survey DO, BOD-5-20, and TOC tests were made on samples obtained from sampling points located both upstream and downstream of the city, and also on the three main tributaries -- the Little Red Deer River, the Medicine River, and the Blindman River -- in the survey area. Sampling points were located as far as 61.5 miles upstream and 50.6 miles downstream of the city.

DO levels of 8 to 11 mg/1 were found upstream of the city's sewage outfall, and DO levels as low as 0.38 mg/1 were found 50 miles downstream. The average ratio of oxygen used to BOD-5-20 removed was 4.22 in the first 20.5 miles downstream of the city's sewage outfall, and

2.40 in the first 50 miles. Although TOC data were incomplete and somewhat inconsistent, the average ratio of oxygen used to TOC removed was 0.50 in the first 20.5 miles downstream of the city's sewage outfall, and 0.88 in the first 50 miles.

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GLOSSARY OF TERMS AND SYMBOLS

BOD	Biochemical Oxygen Demand
BOD-5-0	Biochemical Oxygen Demand at 5 days and $0^{\circ}C$.
BOD-5-20	Biochemical Oxygen Demand at 5 days and $20^{\circ}C$.
c.f.s.	cubic feet per second
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
ft.	feet
hrs.	hours
ins.	inches
mgd	million gallons per day
mg/1	milligrams per liter
ODI	Oxygen Demand Index
TOC	Total Organic Carbon

CHAPTER I

INTRODUCTION

1. Factors Affecting Dissolved Oxygen Concentrations in a River

A commonly used indicator of water pollution is the level of dissolved oxygen in the water. The dissolved oxygen concentration in a river is affected by the amount of physical reaeration, the amount of oxygen produced by photosynthetic organisms present in the river, and the oxygen demand exerted by oxidation of organic material by various aquatic organisms and chemical compounds in the river.

During ice-free periods the amount of oxygen introduced to the river by the first two factors is usually greater than the oxygen used by the third factor.

In the winter periods when most of the river is covered by ice, the balance between oxygen supplied and oxygen used can become critical. The surface area of water exposed to the atmosphere is reduced significantly and physical reaeration is limited to short open stretches of water such as rapids. Also, the winter flows in northern rivers are usually much lower than spring and summer flows, and this limits the amount of oxygen supplied. Photosynthetic

activity of organisms in the river is decreased by the ice cover, which limits penetration of light into the river, and by the low temperature of 0°C. The low temperature of the water decreases the rate of metabolic activity of most of the organisms in the river and thus should decrease the rate of use of oxygen by aquatic organisms as well as the amount supplied by photosynthetic organisms.

When a river is under ice cover under natural conditions a balance can exist between the oxygen supplied and the oxygen used. However, the discharge of wastes from municipalities and industries can adversely affect this balance.

2. The Red Deer River

The Red Deer River rises in the Rocky Mountains approximately 30 miles north of Banff. The river flows northeastwards to the City of Red Deer, and then to the southeast past Drumheller and Empress. The Red Deer River flows into the South Saskatchewan River on the east side of the Alberta-Saskatchewan boundary.

During the winter most of the river, with the exception of a few rapids in the mountain and foothill regions upstream of the City of Red Deer and short open stretches downstream of effluent discharges into the river, is under ice cover. Effluent discharges are from five sources: domestic sewage effluents are discharged into the river at Sundre, the City of Red Deer, the City of

Drumheller, and Empress. Industrial wastes are discharged from a Gulf Oil Canada gas plant near Nevis (approximately 50 miles downstream of the City of Red Deer). The river is also a source of drinking water for the City of Red Deer, the City of Drumheller, and Empress.

3. Oxygen Depletion in the Red Deer River during Periods of Ice Cover

During periods of ice cover the Red Deer River has chronically suffered from severe oxygen depletion downstream of the City of Red Deer; the dissolved oxygen concentrations have been below the recommended minimum limit of 5 mg/1 during the winter months. The cause of the oxygen depletion appears to be the discharge of sewage effluent into the river at the City of Red Deer. The city's sewage, which includes meat packing plant wastes, is treated by a system of anaerobic pits and aerated lagoons which are followed by a final settling lagoon from which the final effluent flows into the river. The five day-20°C biochemical oxygen demand of the final effluent sometimes reaches 200 mg/1 during periods of very cold weather, when the efficiency of treatment is reduced due to the temperature of the sewage in the lagoons.

4. Methods Used to Increase Dissolved Oxygen Levels Downstream of the City of Red Deer

Two methods are being utilized in an attempt to raise dissolved oxygen concentrations downstream of the city. One method is the installation of improved sewage

treatment facilities at the City of Red Deer. Construction of these facilities will not be completed until 1973. In an attempt to improve the dissolved oxygen levels during the winters of 1971-72 and 1972-73, the installation of a U-tube aerator at the Joffre Bridge (approximately 20 miles downstream of the city's sewage outfall) was begun in the fall of 1971, but construction was not completed until the spring of 1972.

5. Objectives of the Investigation

The original purpose of this investigation was to determine the dissolved oxygen concentrations and the oxygen demand in the river at various sampling points in order that the effects of operation of the U-tube aerator could be determined. Due to the late date of completion of construction of the U-tube, very limited data on the effects of operation of the aerator were obtained. Therefore, the investigation assumed the form of a limited analysis of the oxygen depletion under ice cover in the Red Deer River in the 50 miles of river downstream of the City of Red Deer. Oxygen depletion in the river under ice cover upstream of the city was examined in order to determine river conditions upstream of the sewage effluent discharge.

The investigation had several limitations. Limited access to the river and limited time for sampling restricted the number of sampling points that could be visited during each sampling trip. The number of different analyses to be

performed on the samples and the number of duplicates for each analysis of a sample had to be limited because it was impossible to carry large volumes of water samples. No biological survey was undertaken during the investigation.

The tests, which were used to determine the oxygen demand in the rivers and in the sewage effluents during the survey, could not show the exact level of oxygen demand which was present under the natural conditions. However, the tests did show the the relative amounts of oxygen demand under standardized laboratory conditions, which did not duplicate actual stream conditions. The relative values of oxygen demand were useful for the purpose of comparing changes in oxygen demand to changes in dissolved oxygen concentrations in the river.

CHAPTER II

BACKGROUND AND PREVIOUS WORK

1. Physical Characteristics of the Red Deer River

Upstream of the City of Red Deer the river has several of the characteristics of a mountain river. The water is usually clear and has a high dissolved oxygen concentration throughout the year. Reaeration of the river takes place in several rapids which stay ice-free during the winter. These rapids are in the mountain and foothill stretches of the river.

Domestic sewage effluent from septic tanks is discharged to the river at Sundre (population of approximately 1000 people), but does not appear to have much effect on the oxygen demand in the river. There are no other known sources of man-made pollution upstream of the city except for the farms that are located near the banks of the river. It is not known what effects these farms have on the river, but there are farms located near the Red Deer River both upstream and downstream of the city. However, winter pollution from these farms is probably minimal.

Downstream of the City of Red Deer the river undergoes some changes. The water remains fairly clear even after the city's sewage has been added, but has low dissolved oxygen concentrations during the winter months.

During the winter there is very little physical reaeration in the first 50 miles of the river downstream of the city.

Throughout most of this reach the river bottom appears to consist of mostly gravel and rock. High steep banks are common along most of the river's length, particularly in stretch downstream of the City of Red Deer.

During the winter months, ice cover is two to four feet thick with usually less than three feet of water below the ice. Simpson (1971) gives a graphical representation of the statistical flow analysis for the Red Deer River based on river flows measured during the period of 1956 to 1971. The 1% flow is shown to be 178 c.f.s. and the 90% flow is 3000 c.f.s. The maximum flow measured up to March, 1971 was 33,900 c.f.s. and the minimum flow was 102 c.f.s. These flows were all measured at the City of Red Deer. Minimum flows during recent winters were 229 c.f.s. in 1969-70, and 175 c.f.s. in 1970-71.

2. Tributaries

There are three main tributaries in the 110 miles of river studied during this investigation. Two rivers -- the Little Red Deer River and the Medicine River -- flow into the Red Deer River approximately 35 miles upstream of the City of Red Deer. The other tributary -- the Blindman River -- joins the Red Deer River approximately 10 miles downstream of the city. There are also several small streams which do not appear to flow during the winter months.

All of the three main tributaries flow through areas of numerous muskegs. There are also many farmyards situated beside these rivers, and farmers often allow their cattle to wade freely in the rivers. The dissolved oxygen concentrations are very low during the winter months, and the oxygen demands in these rivers are often higher than the oxygen demand in the Red Deer River upstream of the city.

Of the three main tributaries the Medicine River appears to have the largest flows and the Little Red Deer River appears to have the lowest flows. This comparison is based on personal observation and is a very limited comparison because no flow data are available for these rivers. Bouthillier and Simpson (1972) stated that the Medicine and Little Red Deer Rivers had winter flows of approximately 10 c.f.s. each. These measurements were apparently obtained during one sampling trip.

3. City of Red Deer Sewage Treatment

The city uses a system of anaerobic pits and lagoons in the present sewage treatment process which was basically adopted in 1961. Under the original process the raw sewage flowed into four anaerobic pits first and then into three facultative lagoons before being released to the river. The process was modified during the winter of 1969-70 and now the effluent from the anaerobic pits is aerated in the three lagoons. The effluent from the aerated lagoons flows through a final settling lagoon before discharge to the river. The

average total detention time in the process is approximately three days.

The efficiency of removal of biochemical oxygen demand (BOD) during the treatment process varies from approximately 90% during warm weather to 70% during very cold weather. The BOD of the raw influent sewage varies from 300 to 1000 mg/1 while the BOD of the final effluent varies from 30 to 200 mg/1. Average sewage flows are approximately 2.5 mgd. About 30% of the total BOD load to the treatment process is contributed by three meat packing plants in the city. Except for the meat packing plant wastes, the raw influent sewage is mostly domestic sewage.

The City of Red Deer is now upgrading the sewage treatment process by installing a mechanical plant which is expected to remove 96% of the influent BOD. The present facilities will probably be used to treat the meat packing plant wastes before combination with the domestic sewage to be treated in the mechanical plant. Construction of the mechanical plant has not yet been started and will not be completed before 1973.

4. Previous Pollution Surveys of the River

Simpson (1971) analyzed the results of a survey of the Red Deer River which was done during the winter of 1970-71. Samples were obtained once very two weeks from 11 sampling points between the Highway 27 Bridge at Sundre (75 miles upstream of the City of Red Deer sewage outfall) and the

Highway 41 Bridge at Empress (370 miles downstream of the city). This sampling program was in effect from November 12, 1970 to March 17, 1971. An automatic robot monitor was installed at Nevis (50 miles downstream of the city's sewage outfall) in order to obtain a continuous record of dissolved oxygen (DO), temperature, pH, and conductivity. The survey showed that DO levels at Nevis were below the recommended minimum of 5 mg/1 for a total of 89 days during the four months. The lowest values recorded were 0.8 mg/1 at Nevis and 0.7 mg/1 at the City of Drumheller.

Bouthillier and Simpson (1972) analyzed the results of a detailed survey undertaken on January 20, 1971. The survey was accomplished by travelling on snowmobiles in order to obtain samples at intervals of 2 or 3 miles over a total distance of 80 miles of river. The results of the sampling showed that the drop in DO was approximately 2.7 times greater than the drop in BOD (5 day-20°C) and approximately equal to the drop in total organic carbon (TOC).

5. Red Deer River Reaeration Project

As new sewage treatment facilities at the City of Red Deer were not expected to be installed until 1973, a method of maintaining acceptable DO levels in the river through the winters of 1971-72 and 1972-73 was sought. Solodzuk and Bouthillier (1971) examined the feasibility of installing an aerator near the Joffre Bridge which is approximately 20 miles downstream of the city. U-tube

reaeration was suggested as the best method of raising DO concentrations in the river.

The U-tube aerator utilizes the fact that the dissolved oxygen saturation value increases with increasing pressure. It was estimated that if surface water with a DO concentration of 5 mg/1 (saturation value of 13.5 mg/1 at $0^{\circ}C$ at 2200 ft about sea level) is placed under a pressure of 17 psi above atmospheric pressure, the saturation value of DO increases to 30 mg/1 and thus the rate of oxygen transfer to the water is approximately three times as great as at the surface pressure (The rate of transfer is 25 as compared to 8.5).

Bruijn and Tuinzaad (1958) described the results of U-tube experiments at the Municipal Dune Water Works of The Hague, Netherlands. The efficiency of aeration (the increase in DO concentration divided by the original amount below saturation) of the U-tube aerator was found to be approximately 90% when a tube with a depth of 50 ft was used with a head of 38 ins of water. The U-tube aerator was found to have several advantages over the more conventional aeration systems such as the rotating-brush and sprayer aerators. The advantages of the U-tube aeration system were:

(i) greater efficiency,

(ii) less space required for the system,

(iii) no maintenance required,

(iv) little supervision was necessary,

(v) lower costs of construction.

A disadvantage was that no appreciable decrease in carbon dioxide content of the water was obtained.

The U-tube aerator suggested by Solodzuk and Bouthillier (1971) consisted of a 5 ft diameter pipe inside an 8 ft diameter pipe. The water would be forced down the 5 ft pipe to a depth of 40 ft, and would then flow up the 8 ft pipe to the surface. Air would be bubbled into the water in the upper part of the 5 ft pipe. An earth dam across the river was suggested as a means of diverting water into a spillway channel leading into the U-tube. This dam would also provide a head of approximately three to five feet, which would be necessary for operation of the aerator. Estimated cost of installation was $72,000 and estimated cost of operation was $1600 for each of the four winter months when aeration would be necessary. The cost of operation would cover the electricity necessary for operation of the air supply to the aerator.

In the fall of 1971 the Department of the Environment of the Government of Alberta approved the plan and construction was started. Installation of the U-tube aerator, the dam, and the spillway channel was completed in March, 1972. The U-tube aerator was put into operation on March 14 and ran intermittently until March 17 when it was shut down for the winter. Very limited data was obtained on the aerator efficiency and the increase of DO in the river.

6. Methods Used to Evaluate Dissolved Oxygen Concentrations and Oxygen Demand

There are several methods for determination of DO concentrations and oxygen demand. For most unpolluted waters Standard Methods (1971) recommends the azide modification of the iodometric method for the determination of DO concentration. Standard Methods states that this method is the most precise and reliable titrimetric procedure for DO analysis.

Simpson (1970) assessed four procedures for measurement of oxygen demand. These tests were the Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Organic Carbon (TOC), and Oxygen Demand Index (ODI) tests. Of the four tests the BOD test is the only one that measures the reaction rates and the biological processes contributing to the oxygen demand. For this reason it is one of the most widely used tests in pollution control and in monitoring of sewage treatment processes. Its big disadvantage is the period of 5 days required for the test.

Standard Methods (1971) states on page 489 that "the test is of limited value in measuring the actual oxygen demand of surface waters, and the extrapolation of test results to actual stream oxygen demands is highly questionable, since the laboratory environment does not reproduce stream conditions, particularly as related to temperature, sunlight, biological population, water movement and oxygen concentration."

The BOD test however does provide a measurement of relative oxygen requirements for biological oxidation of organic matter in solutions, and also will detect toxicity in wastes.

The COD, TOC, and ODI tests are relatively quick chemical measurements that are extremely useful in assessing industrial wastes of chemical and toxic natures. The COD test is a measurement of the amount of oxygen required for the chemical oxidation of the organic matter in a liquid, the TOC test is a measurement of the organic carbon in the waste, and the ODI test gives the same type of measurement as the COD test. Bouthillier and Simpson (1972) in their study of the Red Deer River found that the COD results were erratic while the TOC results were useful in assessing oxygen demands in the river. The ODI test is a relatively new procedure that has not yet found wide use in pollution control.

All four of the tests are used mainly in assessing the oxygen demands of wastes which are usually much higher than the oxygen demands of river waters. High standard deviations are often obtained with these tests when analyzing samples of low oxygen demand.

CHAPTER III

THE INVESTIGATION

1. General Guidelines for the Survey

The purpose of the investigation was to study the oxygen depletion in the Red Deer River downstream of the City of Red Deer. In order to do this an indication of oxygen depletion upstream of the city had to be obtained as well. Therefore, sampling points had to be chosen in order that oxygen depletion in the river could be documented upstream of the city and for the first 50 miles downstream of the city. Accessibility of sampling locations and time available for sampling had to be considered during the selection of the sampling locations.

It was also necessary to choose the types of analyses to be performed on the river samples. The DO, BOD, and TOC tests were chosen. The COD test was also chosen although its results were thought to be too erratic at river concentrations (Bouthillier and Simpson (1972)).

A sampling program was established by which a 2 to 3 day sampling trip was made once every 2 weeks between December 28, 1971 and April 1, 1972.

2. Sampling Locations

Selection of sampling points for the survey proved to be a problem. Since accessibility was one of the more important criteria, sampling points were chosen at the locations of bridges wherever possible. Because there were few bridges across the Red Deer River a limited number of sampling points were available by this means. The bridges in the survey area included four in the first 60 miles upstream of the city, two at the city, and only two in the first 50 miles downstream of the city. Other than these bridges quick access to the river was limited to farms and oil company roads near the river.

Simpson (1971) listed 11 government sampling locations along 440 miles of the river. Of the eleven, six were in the area to be surveyed in this investigation. These six were visited frequently during this study.

TABLE III-I summarizes the positions of the sampling points chosen for this investigation, and gives the abbreviations that were used when referring to the locations during the study. FIGURE III-I is a map showing the section of river surveyed and indicating the positions of each sampling site.

A bridge across the Red Deer River 20 miles west of Bowden was one of the government sampling points that was used in this survey. This site is 13 miles downstream of Sundre and 61.5 miles upstream of the City of Red Deer's

TABLE III-I

POSITIONS OF SAMPLING LOCATIONS
ON THE RED DEER RIVER

Sampling Location	Abbreviation	Miles Downstream of City's Sewage Outfall
Bridge 20 miles west of Bowden	BH	-61.5
Highway 54 Bridge	54	-23.5
Bridge west of Penhold	P	-18.0
City of Red Deer Water Treatment Plant		
- at water intake	RDw	- 4.5 (w)
- at river	RDr	- 4.5 (r)
City of Red Deer Sewage Treatment Plant	RDS	0.0
Burbank site	B	7.5
Joffre Bridge	J	20.5
Farm	F	29.5
Railway bridge site	RW	40.5
Nevis gas plant	N1	50.0
Highway 21 Bridge	N2	50.6
Little Red Deer River at Red Lodge Provincial Park	LR	Tributary
Medicine River at Highway 54	MR	Tributary
Blindman River at Highway 2A Bridge	BM	Tributary

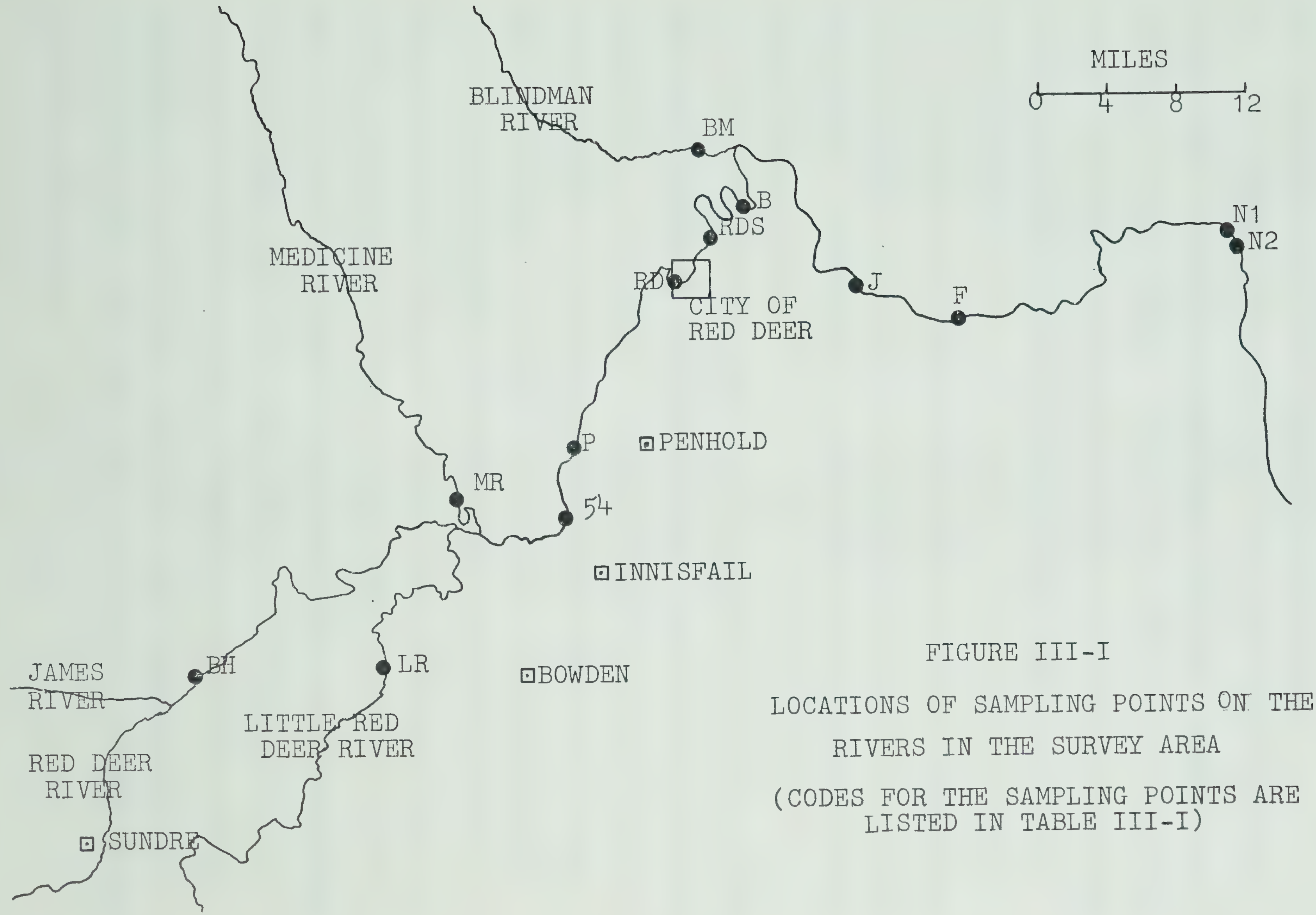

FIGURE III-I

LOCATIONS OF SAMPLING POINTS ON THE RIVERS IN THE SURVEY AREA

(CODES FOR THE SAMPLING POINTS ARE LISTED IN TABLE III-I)

sewage outfall. Due to the time required to travel to this location, this site was only sampled once.

The Highway 54 Bridge over the Red Deer River west of Innisfail was another government sampling location that was used for this survey. This site is 23.5 miles upstream of the city's sewage outfall and is 9 to 10 miles downstream of the confluence of the Red Deer, Little Red Deer, and Medicine Rivers.

A bridge over the Red Deer River west of Penhold was a new sampling location chosen, and was sampled twice during the survey. The site is located 18.0 miles upstream of the city's sewage outfall.

The City of Red Deer Water Treatment Plant was another government sampling location that was used during the survey. Samples were obtained at either the plant's water intake or, whenever possible, from the river beside the plant. This site is 4.5 miles upstream of the city's sewage outfall.

The City of Red Deer Sewage Treatment Plant was another sampling location. Samples were obtained from the river just upstream of the sewage outfall on two occasions, but due to the time required this practice was discontinued. However, samples of the sewage effluent at the plant were obtained on a regular basis. Sampling was not done at the point where the effluent meets the river approximately a quarter of a mile away from the sewage plant as this proved to be too difficult.

The Burbank site, a government sampling point, was the first sampling point downstream of the city. This site, which is 7.5 miles downstream of the sewage outfall, had limited access in that an oil company road was the only approach to it. A steep hill at one section of the road caused difficulties during bad weather and thus this site was not visited on every sampling trip.

The Joffre Bridge was the next sampling location. This site, which is a government sampling point, was also the location of the U-tube aerator. While construction of the U-tube was underway, a narrow section of the dam was left incomplete. The river flowed through this gap in the dam for almost the entire winter and was virtually ice-free most of the time. Whenever possible samples were obtained from this open stretch of water. The Joffre Bridge is approximately 20.5 miles downstream of the city's sewage outfall and 10 miles downstream of the confluence of the Red Deer and Blindman Rivers.

The next sampling point was located 9 miles downstream of the Joffre Bridge. This point was accessible only by travelling to a farmyard in the river valley and, with the farmer's permission, hiking 1/4 to 1/2 mile through deep snow to reach the river. The road to the farmyard was fairly steep and this site was visited only when a four-wheel-drive vehicle was used on a sampling trip.

A point that was 40.5 miles downstream of the city's

sewage outfall was the next sampling location. Access to this site was limited to an oil company road which went 1/2 mile down a steep hill to the river. Samples were obtained only twice from this point during the survey. This site is located within a mile of a railway bridge and thus was referred to as the railway bridge site.

The Gulf Oil Canada gas plant near Nevis was another government sampling location that was visited regularly durin the survey. Whereas the government samples were taken at the plant's water intake which is preceded by 20 to 30 yards of ice-free water, sampling for this survey was done just upstream of the ice-free section. The site is 50 miles downstream of the City of Red Deer's sewage outfall.

Discharge of warm industrial wastes at the gas plant kept a section of the river ice-free for almost a mile throughout the winter. In order to ascertain the amount of aeration in this section of river, samples were obtained at the Highway 21 Bridge which is approximately 0.6 miles downstream of the gas plant.

In addition to sampling the Red Deer River, the three main tributaries were sampled during the survey. The Little Red Deer River was sampled on two occasions at Red Lodge Provincial Park which is 9 miles west of Bowden. Due to thick ice and low flows, finding water was a major difficulty at this site. Samples were regularly obtained at the Highway 54 Bridge over the Medicine River west of Innisfail, and at

the Highway 2A Bridge over the Blindman River north of the City of Red Deer.

3. Sampling Procedures

During each sampling trip an effort was made to obtain samples at as many sites as possible. Due to short hours of daylight it was not always possible to visit all the sites in one day. Furthermore, the river meanders along much of its path, and with the limited number of bridges the distances and travelling times were greater than expected. Consequently a practice of starting at the farthest upstream location and working downstream to all the other sites was not practical. Therefore, the sites visited depended on the time available and the road conditions.

Sampling holes were drilled in the ice by using a 6 inch diameter spoon-shaped ice auger. This was often a laborious process because the ice was sometimes four feet or more in thickness. On many occasions holes were drilled to the maximum length of the auger handle without breaking through the ice layer. Another complication in drilling the holes was the occurrence of two or three layers of ice with water flowing between the layers. This occurred frequently at the Joffre Bridge and Burbank sites as well as by the City of Red Deer Sewage Treatment Plant.

Positions of the sampling holes at each site were chosen with the obvious objective of finding water. After many "dry holes" in the early stages of the survey, choosing

the position of a sampling hole became a process of haphazard guesswork. Whenever a successful "wet hole" was drilled, the position was noted and later holes were usually drilled at the same position. At the Burbank site several holes were drilled on each visit in order that variations of DO and oxygen demand across the river could be determined.

The water samples were obtained by lowering through the holes a dissolved oxygen sampling can which enabled the DO sample bottles to be flushed out at least five times. Two or three DO samples were obtained from each hole and the manganese sulfate, the sodium hydroxide-iodide-azide, and then the concentrated sulfuric acid were added to the DO bottles at the site. The final titration of these samples was performed after returning to the laboratory in Edmonton. The procedure detailed by Standard Methods (1971) was used throughout the DO tests except that, while Standard Methods recommends a maximum delay of a few hours between acidification and titration, a delay of 2 or 3 days was often used during this survey. Titrating the samples in the field did not prove to be practical when attempted, and thus this procedure was not adopted. However, Standard Methods describes storage at temperatures of 10-20°C, and the samples taken during this survey were kept at 0-5°C until titration.

BOD samples were obtained by filling one large glass bottle at each hole. Upon returning to the laboratory the

bottle was placed in a water bath and warmed to 20°C. Aeration to 7 mg/1 of dissolved oxygen was done when necessary. The procedure of Standard Methods was followed for the BOD test. Two seeded bottles (seeded with 10 drops of fresh sewage effluent from the City of Red Deer), two unseeded bottles, and one initial bottle were prepared from each water sample. The BOD bottles were incubated in a water bath at 20°C for 5 days. There was also enough sample remaining to be used in COD tests which were done as described in Standard Methods. The COD results eventually proved to be too erratic and meaningless, and thus were discarded.

TOC samples were obtained by filling one 70 ml plastic bottle at each sample hole. These samples were frozen as soon as possible. Analysis was performed in Calgary by the West Water Quality Subdivision of Environment Canada.

Samples of sewage effluent at the City of Red Deer were obtained from the discharge over the weir of the final settling lagoon. The samples for the BOD tests were prepared and diluted in accordance with the procedures in Standard Methods.

4. Observations and Results

During the survey detailed data on DO, seeded and unseeded BOD, and TOC were obtained from analysis of river samples. Data on BOD's of the final sewage effluent at the

City of Red Deer were also obtained from sewage samples. Additional data concerning a more detailed analysis of samples obtained by the Department of the Environment of the Government of Alberta were supplied by the Division of Pollution Control, and are listed in Appendix B. Data on the daily discharges of the river at the City of Red Deer were obtained from the Water Resources Division of the Department of the Environment, and are listed in Appendix C. Detailed data on the operation of the City of Red Deer Sewage Treatment Plant were obtained from the City Engineer, and are listed in Appendix D.

The observations and results from each sampling trip are summarized in the following portion of the report. Detailed data for each sampling location are shown in Appendix A.

(a) Sampling Trip of December 28-31, 1971

Five sampling locations were visited during this trip, and the BOD and DO data obtained are summarized in TABLE III-II. The results are shown graphically in FIGURE III-II. However, since only three sampling locations on the Red Deer River were visited, the usefulness of the data was very limited. The data does show clearly the drop in DO from the city to the Joffre Bridge. The DO level at Joffre Bridge was below the suggested minimum of 5 mg/1.

The daily variation of the sewage effluent's BOD on December 30, 1971 was determined by taking samples once every 4 hours during the day. The results are tabulated in

TABLE III-III and shown graphically in FIGURE III-III.

The Red Deer River had about 3 feet of ice cover at the locations sampled, and the Little Red Deer River had about the same. The Medicine River had 1½ feet of ice cover at the sampling point. Air temperatures were 20-30°F at the times of sampling.

TABLE III-II

DO AND BOD DATA FROM SAMPLING TRIP

OF DECEMBER 28-31, 1971

Sampling Location	Date of Sampling	DO	BOD-5-20 (seeded)
-4.5 miles (r)	Dec. 28	9.62mg/1	1.72mg/1
+20.5 miles	Dec. 28	4.43	3.40
Little Red Deer R.	Dec. 29	6.11	3.62
Medicine R.	Dec. 30	4.20	2.40
-23.5 miles	Dec. 30	10.45	2.06

TABLE III-III

DAILY VARIATION OF BOD OF SEWAGE EFFLUENT

AT THE CITY OF RED DEER ON DECEMBER 30, 1971

Time of Sampling	BOD-5-20	Coefficient of Variation
0100 hrs	63.2 mg/1	8.29%
0500 hrs	83.9	6.73
0900	70.6	10.87
1300	70.2	16.39
1700	93.8	8.76
2100	74.4	12.21
Average	76.0	10.54

TABLE III-IV

DO AND BOD DATA FROM SAMPLING TRIP

OF JANUARY 11, 1972

Sampling Location	Date of Sampling	DO	BOD-5-20 (unseeded)
-4.5 miles (w)	Jan. 11	8.20mg/1	---
0 miles	Jan. 11	8.56	---
+7.5 miles Hole #1	Jan. 11	6.52	2.24mg/1
#2	Jan. 11	6.41	3.32
#3	Jan. 11	6.39	1.80
#4	Jan. 11	6.40	2.12
#5	Jan. 11	6.32	0.64
+20.5 miles	Jan. 11	3.65	1.64

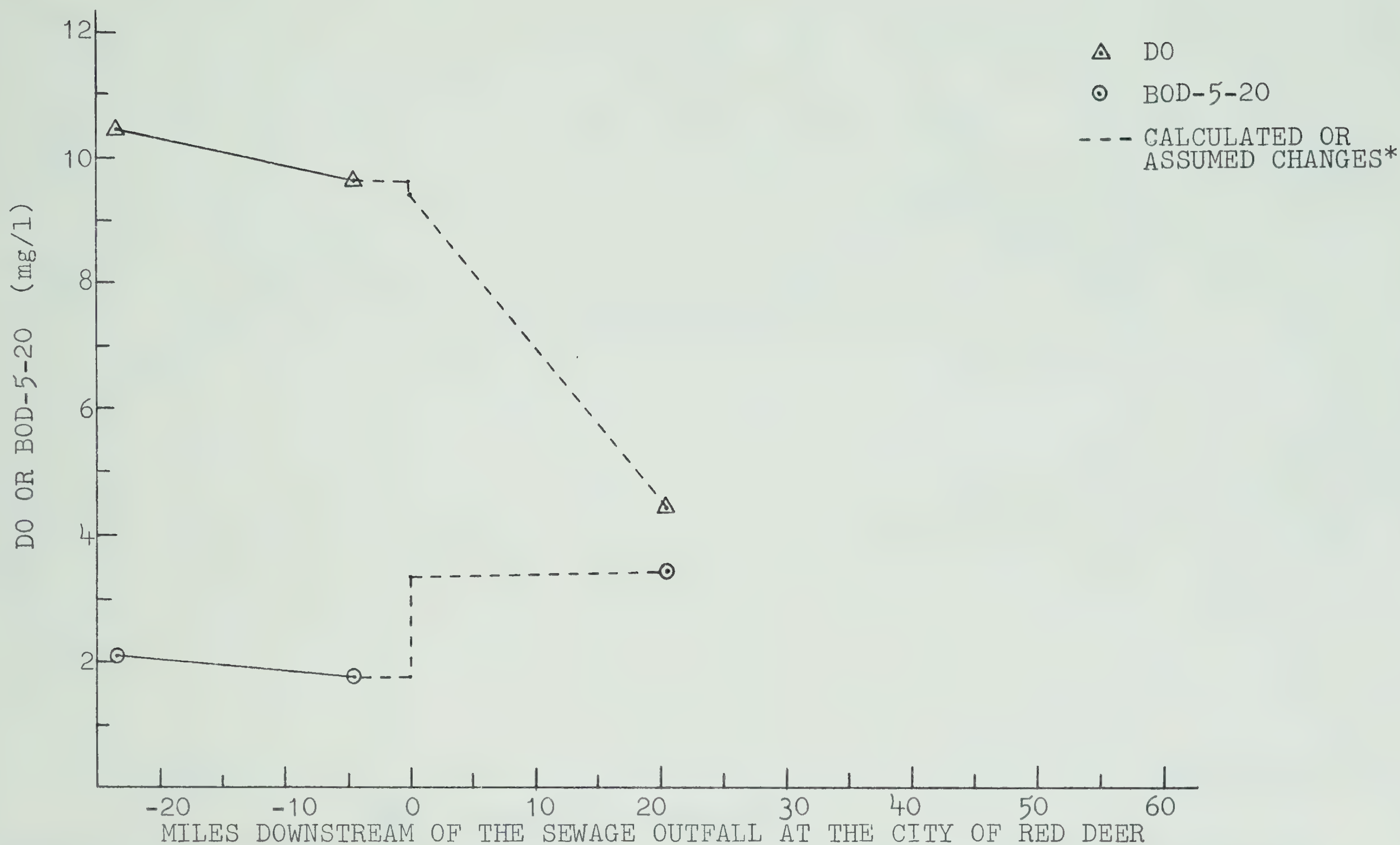

FIGURE III-II DO AND BOD PROFILES OF THE RED DEER RIVER ON DECEMBER 28-30, 1971

* Changes at Mile 0 are discussed on pages 63 to 70.

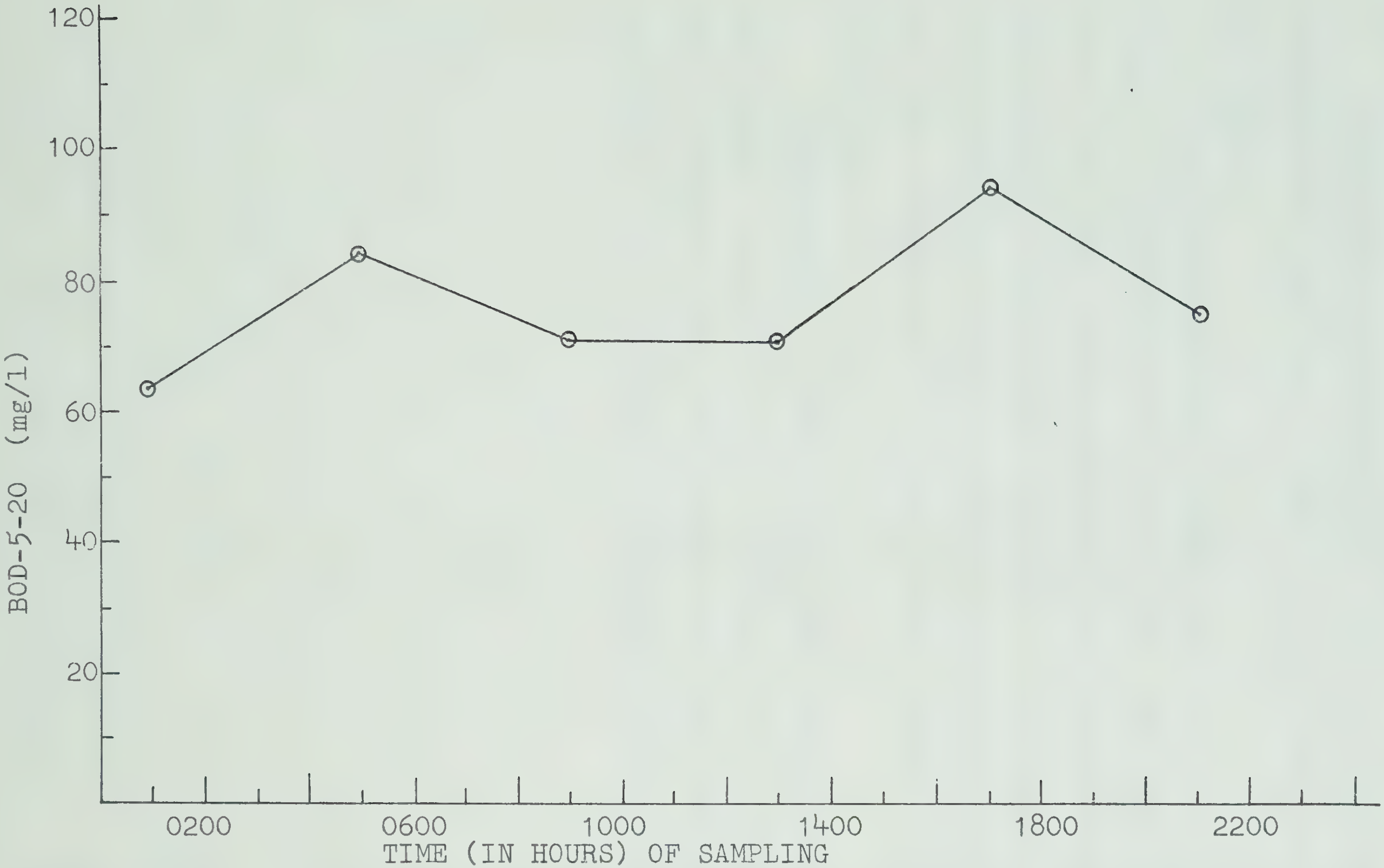

FIGURE III-III DAILY VARIATION OF BOD OF SEWAGE EFFLUENT AT THE CITY OF RED DEER ON DECEMBER 30, 1971

(b) Sampling Trip of January 11, 1972

TABLE III-IV and FIGURE III-IV give the results of the analyses of the samples which were obtained during this trip.

The oxygen depletion between the city and the Joffre Bridge was clearly shown by the DO data. BOD data for the river at the city were unfortunately not obtained and thus the change in oxygen demand could not be determined. Variations in DO and BOD across the river at the Burbank site were determined by drilling 5 holes spaced 10 yards apart across the river.

Approximately 3 feet of ice cover were present at the sampling locations. The Burbank and Joffre Bridge sites had two thinner layers of ice which were separated by flowing water. Air temperatures were approximately 10-15°F.

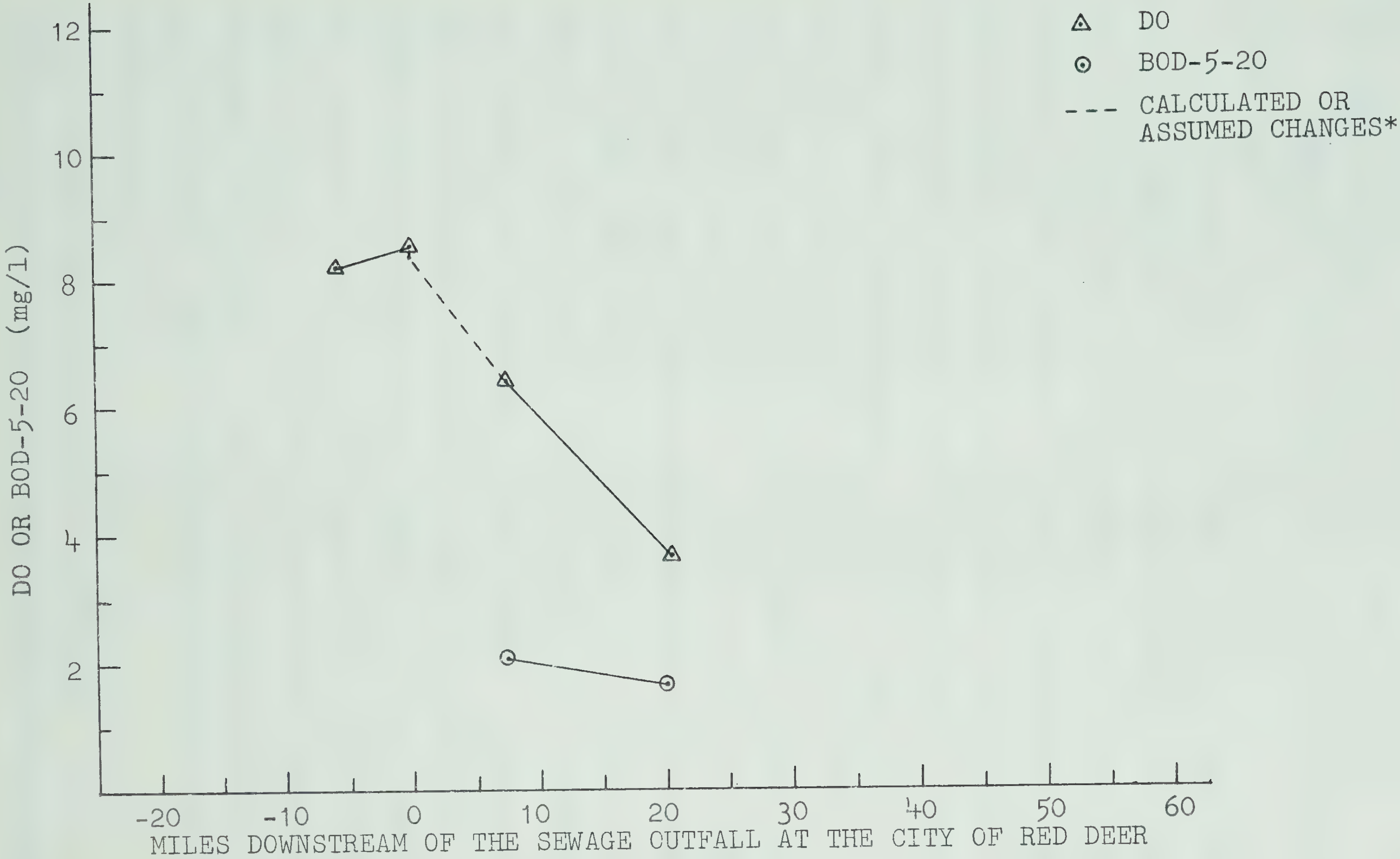

FIGURE III-IV DO AND BOD PROFILES OF THE RED DEER RIVER ON JANUARY 11, 1972

* Changes at Mile 0 are discussed on pages 63 to 70.

(c) Sampling Trip of February 1-2, 1972

TABLE III-V and FIGURE III-V show the data obtained on this trip.

One item of interest in TABLE III-V is the difference in BOD of the two Joffre Bridge water samples which were taken $5\frac{1}{2}$ hours apart. This illustrates one of the main problems of river sampling -- that is, obtaining a representative sample. Although the two samples were obtained from the same hole, the difference in BOD amounted to almost 3 mg/1: the DO concentrations, however, were almost equal. There is a possibility that when the hole was drilled the first time, the ice auger disturbed matter on the river bottom which was only a foot or two below the ice cover. Some of this matter may have been included in the water sample and, while the matter would not have likely had any effect on the DO value, it would probably have increased the values of the BOD and TOC test results. This may have also occurred with other samples taken from various locations during other sampling trips. There is a strong possibility that several of the river BOD samples were contaminated by benthic material in this manner because the bottom of the ice cover lay within 1 to 2 ft of the river bottom at a majority of the sampling holes and also because the river flows were low.

Another item of interest in TABLE III-V is the difference in DO between the sample taken from the water

TABLE III-V

DO AND BOD DATA FROM SAMPLING TRIP

OF FEBRUARY 1-2, 1972

Sampling Location	Date of Sampling	DO	BOD-5-20 (seeded)
-4.5 miles (r)	Feb. 1	9.29mg/1	1.60mg/1
-4.5 miles (w)	Feb. 1	7.96	---
0 miles	Feb. 1	9.51	0.74
+20.5 miles	Feb. 1 (1100hrs)	3.73	6.55
+20.5 miles	Feb. 1 (1630hrs)	3.71	2.74
+50.0 miles	Feb. 1	0.38	4.08
-23.5 miles	Feb. 2	8.56	2.12
Medicine R.	Feb. 2	0.32	1.34
Blindman R.	Feb. 2	3.87	0.88

intake well at the City of Red Deer Water Treatment Plant and the sample taken from the river beside the plant. The river DO was 1.33 mg/1 higher than that of the water from the water intake well. The reason for this difference is not known, but it should be noted that all government samples for this sampling point have been obtained from the intake well. For the remainder of the survey, all samples for this site were obtained from a hole drilled in the river ice whenever possible.

Another point of interest in TABLE III-V is the DO

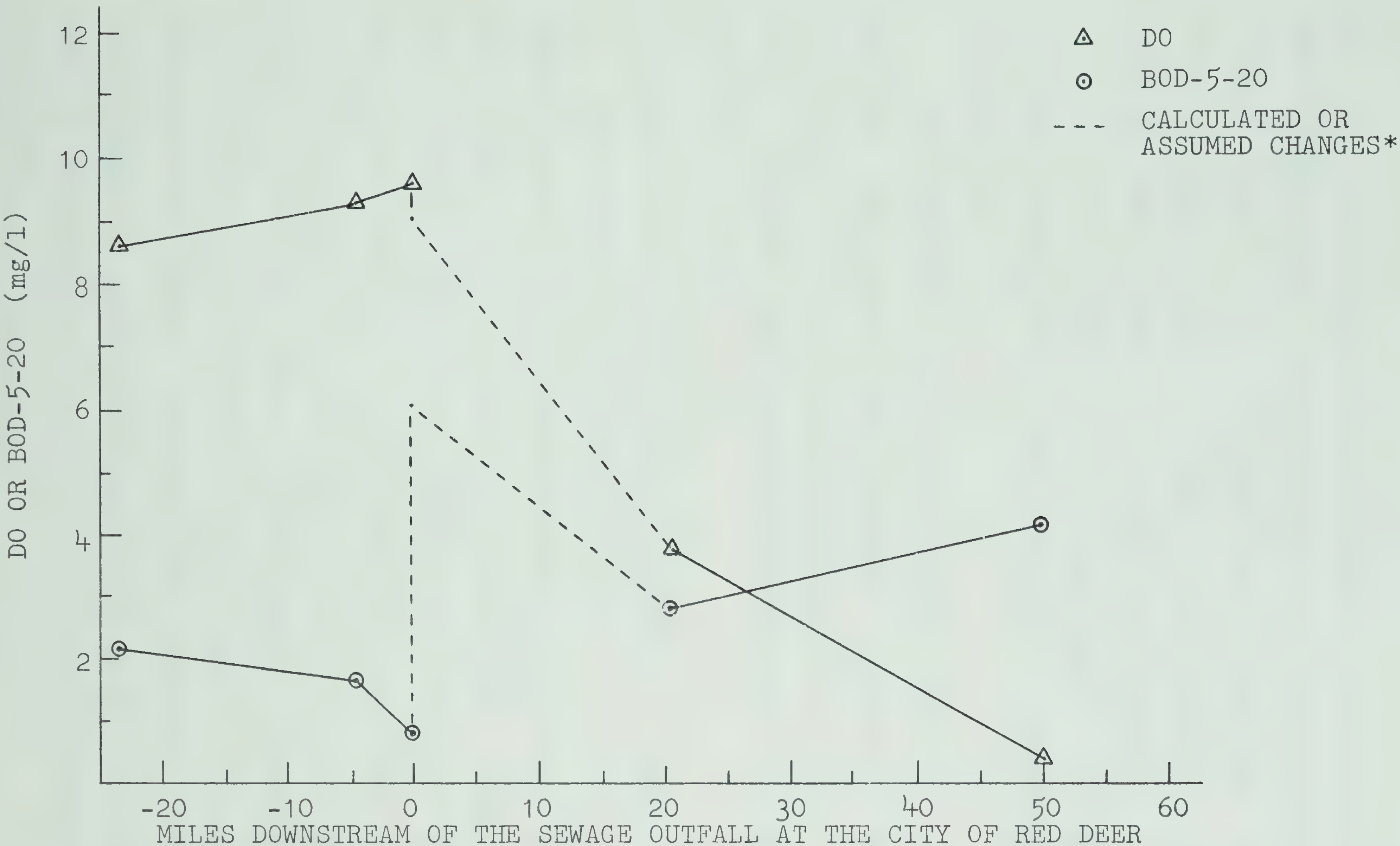

FIGURE III-V DO AND BOD PROFILES OF THE RED DEER RIVER ON FEBRUARY 1-2, 1972

* Changes at Mile 0 are discussed on pages 63 to 70.

value of 0.38 mg/1 which was obtained for a sample taken at the Nevis gas plant. This value was the lowest known recorded DO value for the Red Deer River. The value obtained for the Medicine River site was 0.32 mg/1 which was the lowest DO value recorded during the entire survey.

Ice cover on the river was approximately the same as on the previous trip. Air temperatures were between -15°F and 0°F.

The sampling site on the Blindman River had thin ice cover which varied from a couple of inches to a foot in thickness. The water was approximately a foot in depth and thus problems were experienced when using the sampler to obtain DO samples.

(d) The Little Red Deer River on February 13, 1972

On February 13 an attempt was made to procur a sample from the Little Red Deer River at Red Lodge Provincial Park which is 9 miles west of Bowden. Eight holes were drilled in an attempt to find water. Of these eight only one was successful in hitting water under the ice cover: when the ice auger broke through the ice, the water rose up ½ inch into the hole giving a total depth of approximately 2 ins of water. Another hole reached a pocket of water that lay between ice layers. Although this water did not appear to be flowing, a sample was taken to be tested for BOD. The BOD-5-20 (seeded) was 3.66mg/1. It was not possible to procur a satisfactory DO sample.

Ice thickness appeared to vary from 3 to 5 ft. Air temperature was 26°F.

(e) Sampling Trip of February 15-16, 1972

The results listed in TABLE III-VI, and illustrated graphically in FIGURE III-VI, showed generally higher DO levels than those of previous sampling trips. The main reason for this was the air temperatures (35-40°F) that prevailed at the time, and as a result of the higher temperatures the river was flowing over the ice surface at several locations in the survey area. Therefore, physical

TABLE III-VI

DO, BOD, AND TOC DATA FROM SAMPLING TRIP OF FEBRUARY 15-16, 1972

Sampling Location	Date of Sampling	DO	BOD-5-20 (seeded)	TOC
Medicine R.	Feb. 15	0.93mg/1	2.12mg/1	9mg/1
-23.5 miles	Feb. 15	9.75	3.05	4
- 4.5 miles (r)	Feb. 15	9.18	1.45	3
+20.5 miles	Feb. 15	6.34	2.39	7
+50.0 miles	Feb. 15	4.45	0.82	5
+50.6 miles	Feb. 15	6.64	0.69	4
- 4.5 miles (r)	Feb. 16	9.22	2.19	6
+ 7.5 miles Hole #1	Feb. 16	6.58	2.01	5
Hole #2	Feb. 16	6.50	1.68	4
+20.5 miles	Feb. 16	6.12	1.29	3
Blindman R.	Feb. 16	3.98	0.68	6

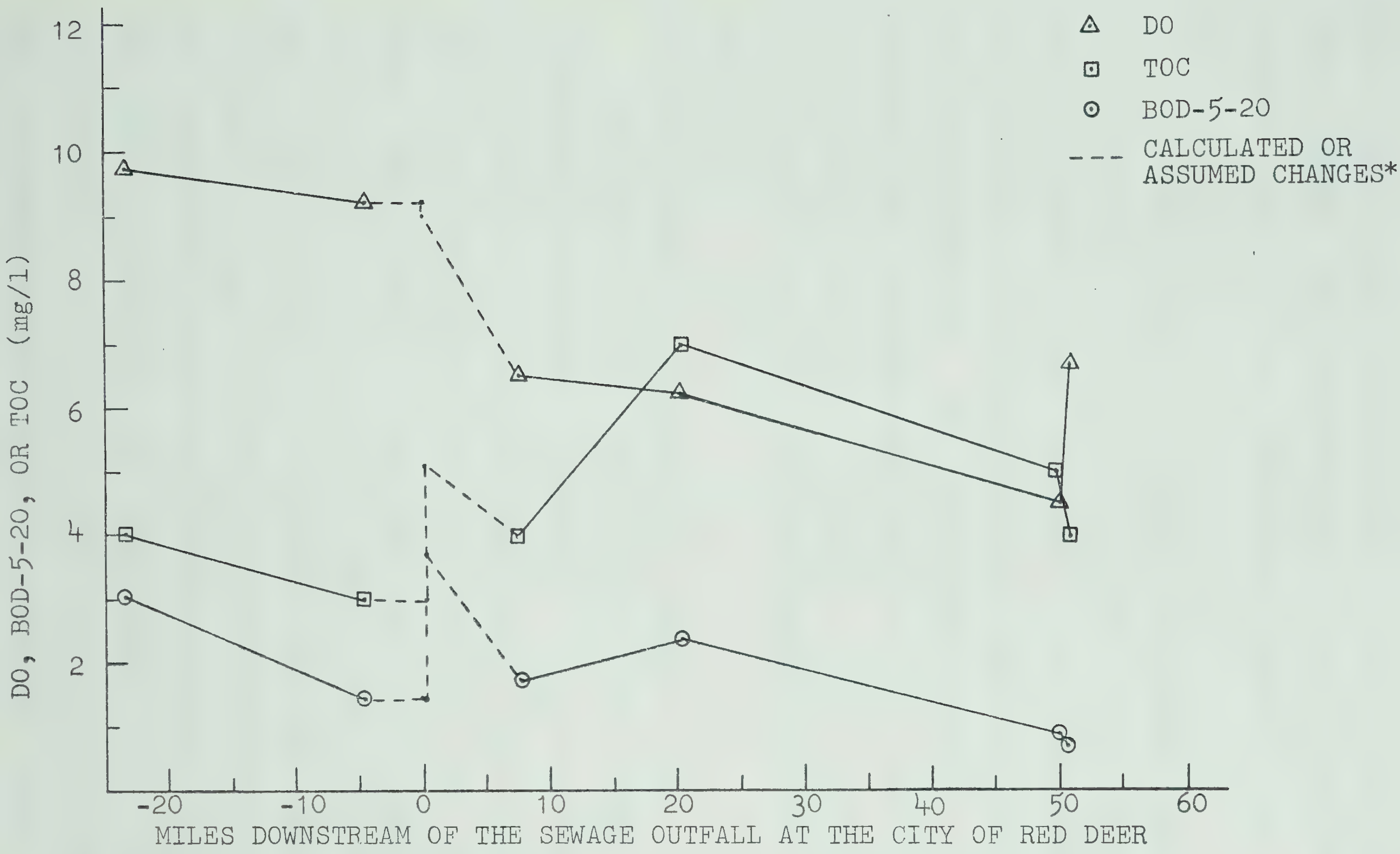

FIGURE III-VI DO, BOD, AND TOC PROFILES OF THE RED DEER RIVER ON FEBRUARY 15-16, 1972

* Changes at Mile 0 are discussed on pages 63 to 70.

reaeration was replacing oxygen that had been used in the river. Despite this reaeration the DO level at the Nevis gas plant was still below the minimum acceptable limit of 5 mg/1.

The data for the BOD and TOC tests showed somewhat erratic behaviour. For example, the TOC at the city on Feb. 16 was twice as high as on Feb. 15 while the TOC at Joffre Bridge on Feb. 15 was more than twice as high on Feb. 15 as on Feb. 16. BOD results showed higher levels upstream of the sewage outfall than were found downstream. A 3-hole cross section was attempted at Burbank, but due to inclement weather only two holes were drilled and sampled.

(f) Sampling Trip of February 29 - March 2, 1972

The results, which are listed in TABLE III-VII and illustrated graphically in FIGURE III-VII, indicated that the DO levels were much lower than they had been on February 15-16. The DO measurements showed that four downstream sites -- Joffre Bridge, the farm, the railway bridge, and the Nevis gas plant sites -- were below 5 mg/1. The readings of 0.88 and 0.74 mg/1 at the Nevis gas plant were the lowest readings obtained for the Red Deer River during the survey except for the two readings obtained during the sampling trip of February 1-2. An increase of 1.24 mg/1 of DO from the Joffre Bridge to the farm site was likely due to an open stretch of water at the Joffre Bridge. In

TABLE III-VII

DO, BOD, AND TOC DATA FROM SAMPLING TRIP

OF FEBRUARY 29-MARCH 2, 1972

Sampling Location	Date of Sampling	DO	BOD-5-20 (seeded)	TOC
-4.5 miles (r)	Feb. 29	8.17mg/1	3.02mg/1	4mg/1
+20.5 miles	Feb. 29	3.75	1.53	3
+29.5 miles	Feb. 29	4.99	4.30	5
+50.0 miles	Feb. 29	0.88	2.21	7
+50.6 miles	Feb. 29	--	1.22	7
Medicine R.	Mar. 1	0.97	2.98	16
-23.5 miles	Mar. 1	9.20	4.02	5
-4.5 miles (r)	Mar. 1	8.74	--	10
+7.5 miles				
Hole #1	Mar. 1	5.76	3.98	6
Hole #2	Mar. 1	6.36	3.36	7
Hole #3	Mar. 1	6.68	--	7
Blindman R.	Mar. 1	3.76	1.68	8
+20.5 miles	Mar. 1	--	1.72	7
+29.5 miles	Mar. 1	2.41	--	4
+40.5 miles	Mar. 1	2.62	2.52	4
-23.5 miles	Mar. 2	9.48	--	3
+7.5 miles Hole #2	Mar. 2	6.10	--	5
+20.5 miles	Mar. 2	2.82	2.23	27
+50.0 miles	Mar. 2	0.74	1.92	4

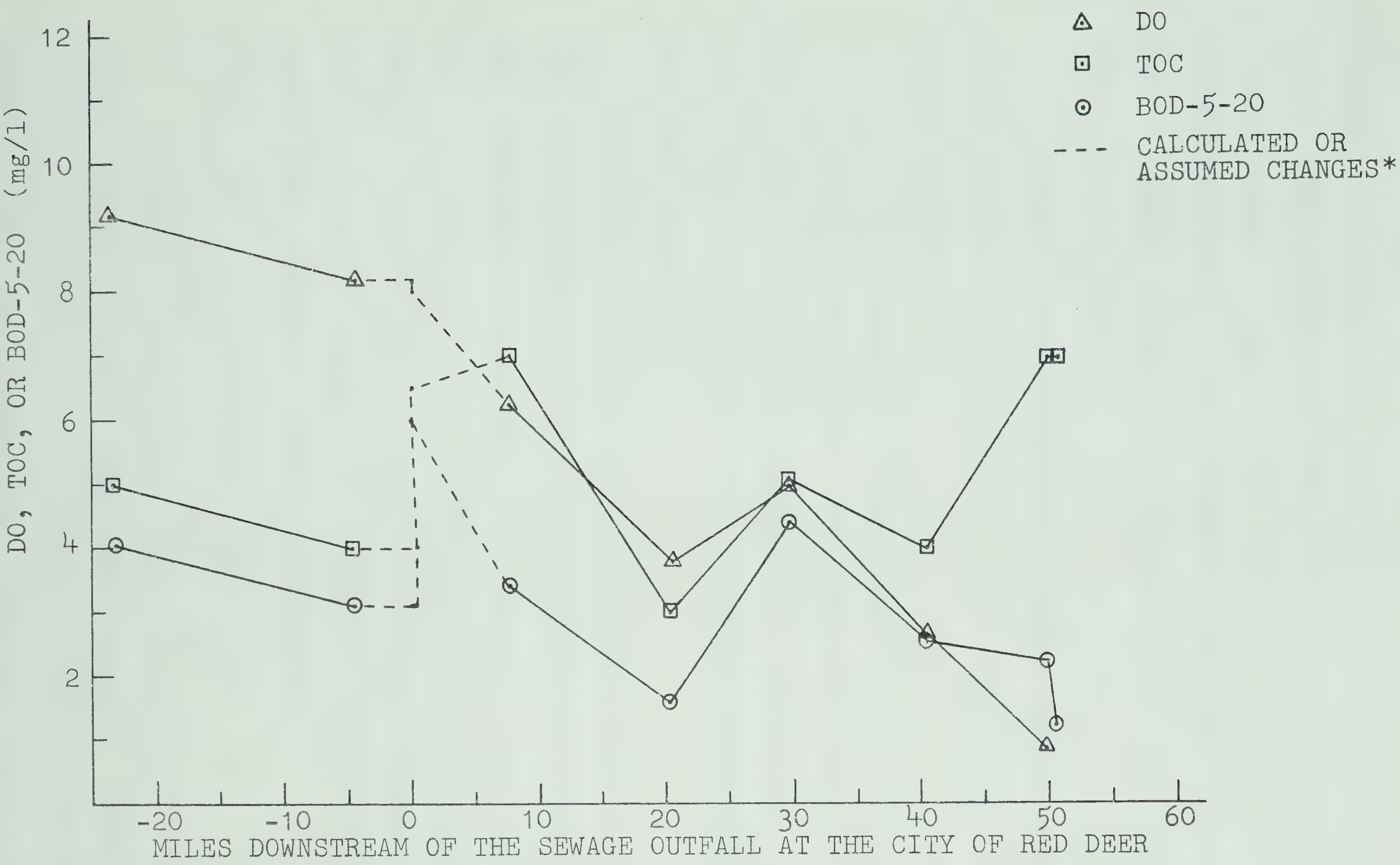

FIGURE III-VII DO, BOD, AND TOC PROFILES OF THE RED DEER RIVER ON FEBRUARY 29 TO MARCH 2, 1972

* Changes at Mile 0 are discussed on pages 63 to 70.

preparing for completion of the dam at the aerator site, a construction crew had ripped out all the ice that had been in the channel through the dam. The open section of river was approximately 15 yards wide and less than 20 yards long. A small vortex had formed where the river flow disappeared under the ice.

A major factor causing the low DO levels appeared to be the low flows which coincided with the low temperatures of $-30^{\circ}F$ to $-20^{\circ}F$.

The BOD results showed unusually high levels of oxygen demand in the river. The reason for the high values is not clear, but the BOD results were significantly greater than 2 mg/l at all sites except the Joffre Bridge and the Nevis gas plant.

The TOC results displayed increases downstream of the city and also downstream of the railway bridge site. However, during the three days, TOC values of 4 mg/l and 10 mg/l were obtained at the City of Red Deer Water Treatment Plant; values of 3 mg/l, 7 mg/l, and 27 mg/l were obtained at the Joffre Bridge. Consequently, the merit of these TOC results was considered rather questionable.

(g) Sampling Trip of March 15-17, 1972

On March 14 operation of the U-tube aerator near the Joffre Bridge was begun. Operation continued through March 15 and partly into March 16. On March 15 some interruptions in operation were experienced while adjustments were made on

the depth of immersion of the air bubbler in the U-tube. Due to overheating in the compressor shack, the compressor was automatically shut off -- probably on the morning of March 16. Only sporadic operation of the aerator was maintained during the afternoon of March 16 and the morning of March 17, and the aerator was not used after that date.

Sampling was hampered somewhat by dangerous ice conditions which were caused by warm air temperatures ranging from 35°F to 55°F during the three days. Although the ice was very soft and pressure ridges were appearing in many places, thicknesses of 3 to 4 feet of ice were common at most sampling locations. Storm sewer runoff at the City of Red Deer made conditions too dangerous to sample from the river by the water treatment facilities and therefore the samples for this location were obtained from the water intake well. With the exception of Joffre Bridge, all other samples were obtained by venturing bravely onto the ice surface of the river to drill holes (It is interesting to note that the ice on the river broke up on March 20). At the time of this sampling trip there were some open stretches of water at several locations, including upstream of the Joffre Bridge and downstream of the aerator site.

The DO, BOD, and TOC results are tabulated in TABLE III-VIII. The results of samples taken on March 15-16, which were days of aerator operation, are illustrated graphically in FIGURE III-IX.

The river on March 15-16 was characterized by high DO values upstream of the city, and by considerably lower DO values downstream of the city. At the U-tube intake the DO was below the minimum acceptable limit of 5 mg/1. The DO level of water passing through the U-tube was raised to levels of 5.5 to 6.5 mg/1. Only part of the flow of the river was going through the U-tube and the remainder of the flow was going over the dam spillway; it is not known how much aeration took place on the dam spillway. It is also not known whether there was any seepage through the dam.

At the farm 9 miles downstream of the aerator, the river's DO levels were 2 mg/1 higher on March 16 than on March 17. While there were open stretches of water between the two sites, the difference of 2 mg/1 was probably due largely to aeration at the U-tube site. However, the DO level at the farm on March 16 was also 2.64 mg/1 higher than the DO level of the water aerated in the U-tube. This increase was likely due to the aeration in the open stretches of river downstream of the aerator. On March 17 the difference was 1.80 mg/1 while the aerator was not in operation; since the aerator had not been in operation for almost a day previous to the time that these samples were taken, the latter difference was probably due almost entirely to physical reaeration in the river.

The BOD results showed slight differences along the length of the river. The BOD was surprisingly high at the

TABLE III-VIII

DO, BOD, AND TOC DATA FROM SAMPLING TRIP

OF MARCH 15-17, 1972

Sampling Location	Date of Sampling	DO	BOD-5-20 (seeded)	TOC
-61.5 miles	Mar. 15	12.05mg/1	2.49mg/1	3mg/1
Medicine R.	Mar. 15	1.08	2.52	8
-23.5 miles	Mar. 15	10.95	1.96	8
-4.5 miles (w)	Mar. 15	10.08	2.08	6
+7.5 miles				
Hole #1	Mar. 15	6.70	2.86	23
Hole #2	Mar. 15	7.04	2.57	6
Hole #3	Mar. 15	7.90	3.16	6
Blindman R.	Mar. 15	5.54	1.59	28
+20.5 miles				
intake	Mar. 15	3.92	3.40	8
outlet	Mar. 15	5.59	--	7
-23.5 miles	Mar. 16	10.72	1.98	6
-18.0 miles	Mar. 16	10.70	2.69	8
-4.5 miles (w)	Mar. 16	10.22	1.86	11
+7.5 miles				
Hole #1	Mar. 16	7.05	3.58	10
Hole #2	Mar. 16	7.77	3.00	5
Hole #3	Mar. 16	8.00	3.64	6
+20.5 miles				
intake	Mar. 16	4.58	2.36	14
outlet	Mar. 16	6.54	--	8
+29.5 miles	Mar. 16	9.18	3.03	6
+20.5 miles				
intake	Mar. 17	5.12	2.47	8
outlet	Mar. 17	5.16	--	-
dam	Mar. 17	---	2.15	5
+29.5 miles	Mar. 17	6.96	1.92	5
+40.5 miles	Mar. 17	8.02	2.64	5
+50.0 miles	Mar. 17	7.28	2.46	10
+50.6 miles	Mar. 17	8.70	2.03	5

The samples taken at the aerator outlet at Joffre Bridge were obtained while the aerator was in partial operation on March 15 and 16, and while it was shut off on March 17.

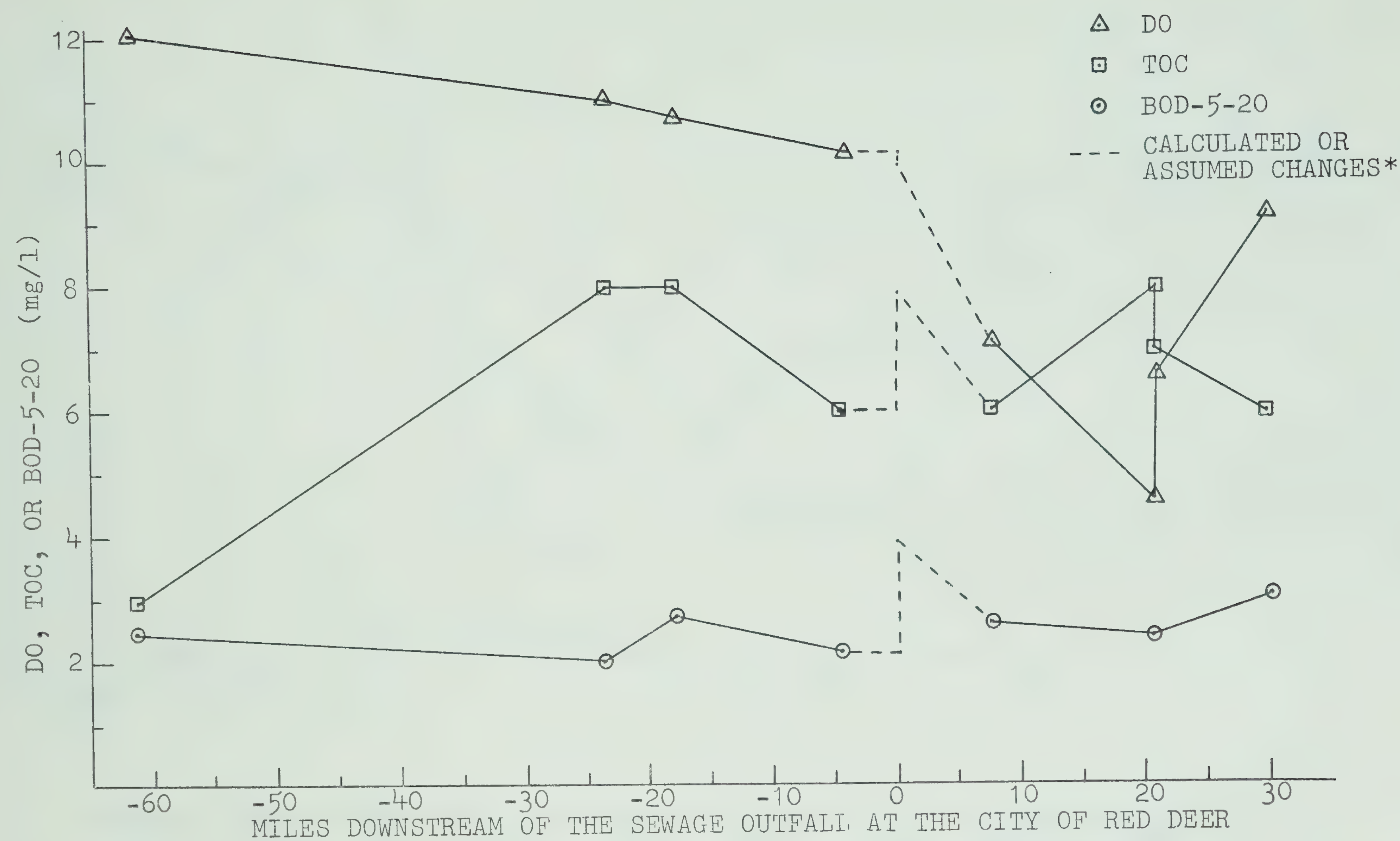

FIGURE III-VIII DO, BOD, AND TOC PROFILES OF THE RED DEER RIVER ON MARCH 15-16, 1972 DURING PARTIAL OPERATION OF THE AERATOR

* Changes at Mile 0 are discussed on pages 63 to 70.

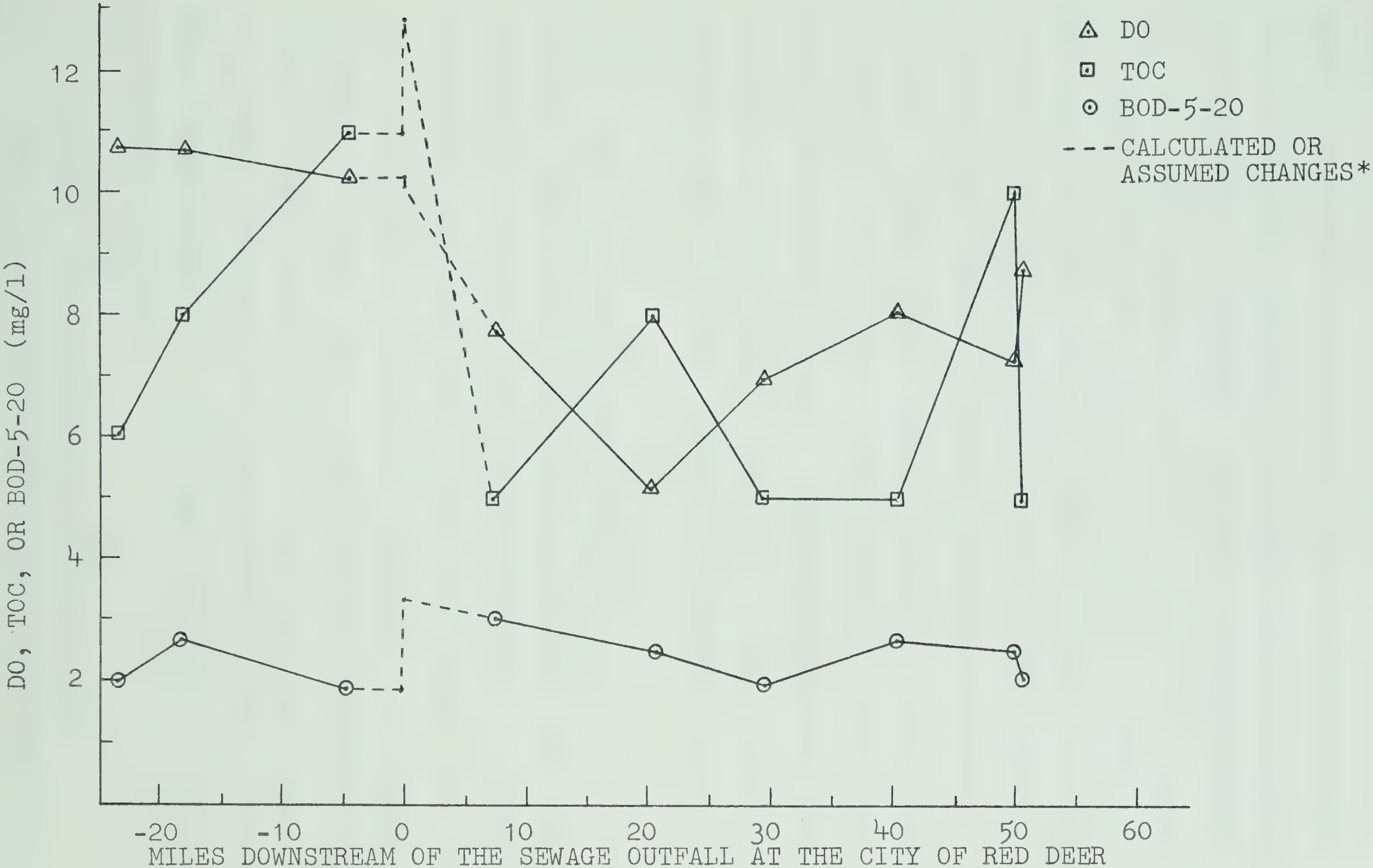

FIGURE III-IX DO, BOD, AND TOC PROFILES OF THE RED DEER RIVER ON MARCH 16-17, 1972

* Changes at Mile 0 are discussed on pages 63 to 70.

bridge 20 miles west of Bowden. At this location the BOD of 2.49 mg/1 was higher than the values obtained by the government in previous surveys; an average BOD of 0.8 mg/1 with a maximum value of 1.9 mg/1 was reported by Simpson (1971) for the winter of 1970-71. The river's BOD decreased, even with the addition of the flows of the Medicine and Little Red Deer Rivers, to approximately 2 mg/1 at the Highway 54 Bridge but increased again to 2.69 mg/1 at the bridge west of Penhold. This increase in BOD may have been due to the presence of several feedlots in the area, but this is merely speculation. The BOD value decreased to 2 mg/1 at the City of Red Deer, and increased again after the discharge of sewage effluent to the river.

The TOC results showed rather erratic values. Values of 6 mg/1 and 11 mg/1 were determined at the city. In the river cross section at the Burbank site, an unacceptable value of 23 mg/1 was found for the first sample hole while values of 6 mg/1 were found for the other two sample holes; a value of 10 mg/1 for the first Burbank hole was found on March 16 while values of 5 mg/1 and 6 mg/1 were found for the second and third holes respectively. These holes were spaced approximately 15 yards apart in a river width of approximately 60 yards.

(h) Sampling Trip of March 31 - April 1, 1972

The ice on the Red Deer River in the survey area

broke up on March 20, and by the time of this sampling trip the river discharge was approximately 15 times that of March 15-17. As a result the DO levels were fairly high at every sampling point. The results are tabulated in TABLE III-IX and shown graphically in FIGURE III-X. The river BOD values at the Medicine River and Joffre Bridge sampling sites were higher than the average winter values, and the other BOD values were only slightly higher than the normal winter values. The Medicine River was mostly ice-free as was the Blindman River. The Little Red Deer and Blindman Rivers were not sampled. Many of the smaller streams feeding the Red Deer River were flowing on this date.

The water temperature of the Red Deer River was still 0°C while air temperatures varied from 25°F to 55°F. Most of the water samples had a clear rusty color and contained more silt than the samples that were taken during the winter.

Daily variation in BOD of the City of Red Deer sewage effluent between 1400 hrs, March 31, and 1200 hrs, April 1, were determined by taking a number of samples at regular intervals. The data is tabulated in TABLE III-X and illustrated graphically in FIGURE III-XI.

The aerator at the Joffre Bridge was not in operation, and virtually no flow was going through the U-tube. A section of the dam had been washed away by the river, and the river was flowing through this gap.

TABLE III-IX

DO AND BOD DATA FROM SAMPLING TRIP

OF MARCH 31-APRIL 1, 1972

Sampling Location	Date of Sampling	DO	BOD-5-20 (seeded)
+50.6 miles	Mar. 31	10.14mg/1	3.14mg/1
Medicine R.	Apr. 1	8.06	5.13
-23.5 miles	Apr. 1	10.81	2.15
-18.0 miles	Apr. 1	10.00	3.24
-4.5 miles (w)	Apr. 1	10.57	2.52
+20.5 miles	Apr. 1	9.61	6.64

TABLE III-X

DAILY VARIATION OF BOD OF SEWAGE EFFLUENT

AT THE CITY OF RED DEER

ON MARCH 31-APRIL 1, 1972

Date and Time of Sampling	BOD-5-20	Coefficient of Variation
Mar. 31--1400hrs	42.0mg/1	6.98%
1600	41.0	4.46
2000	34.3	7.14
Apr. 1--0000	33.1	19.09
0800	64.2	8.88
1000	65.5	9.37
1200	67.0	5.00
Average	49.6	8.70

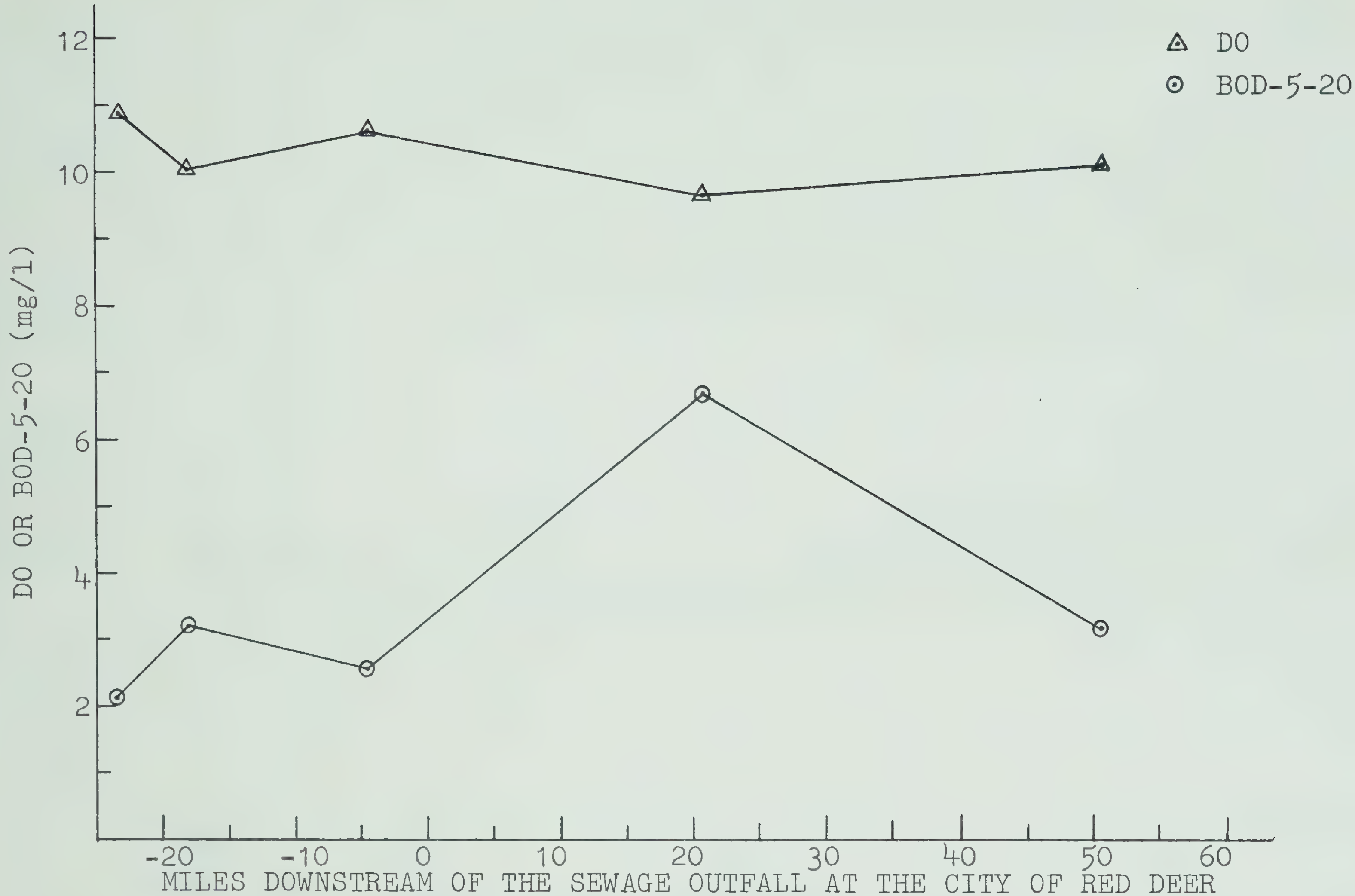

FIGURE III-X DO AND BOD PROFILES OF THE RED DEER RIVER ON MARCH 31 TO APRIL 1, 1972

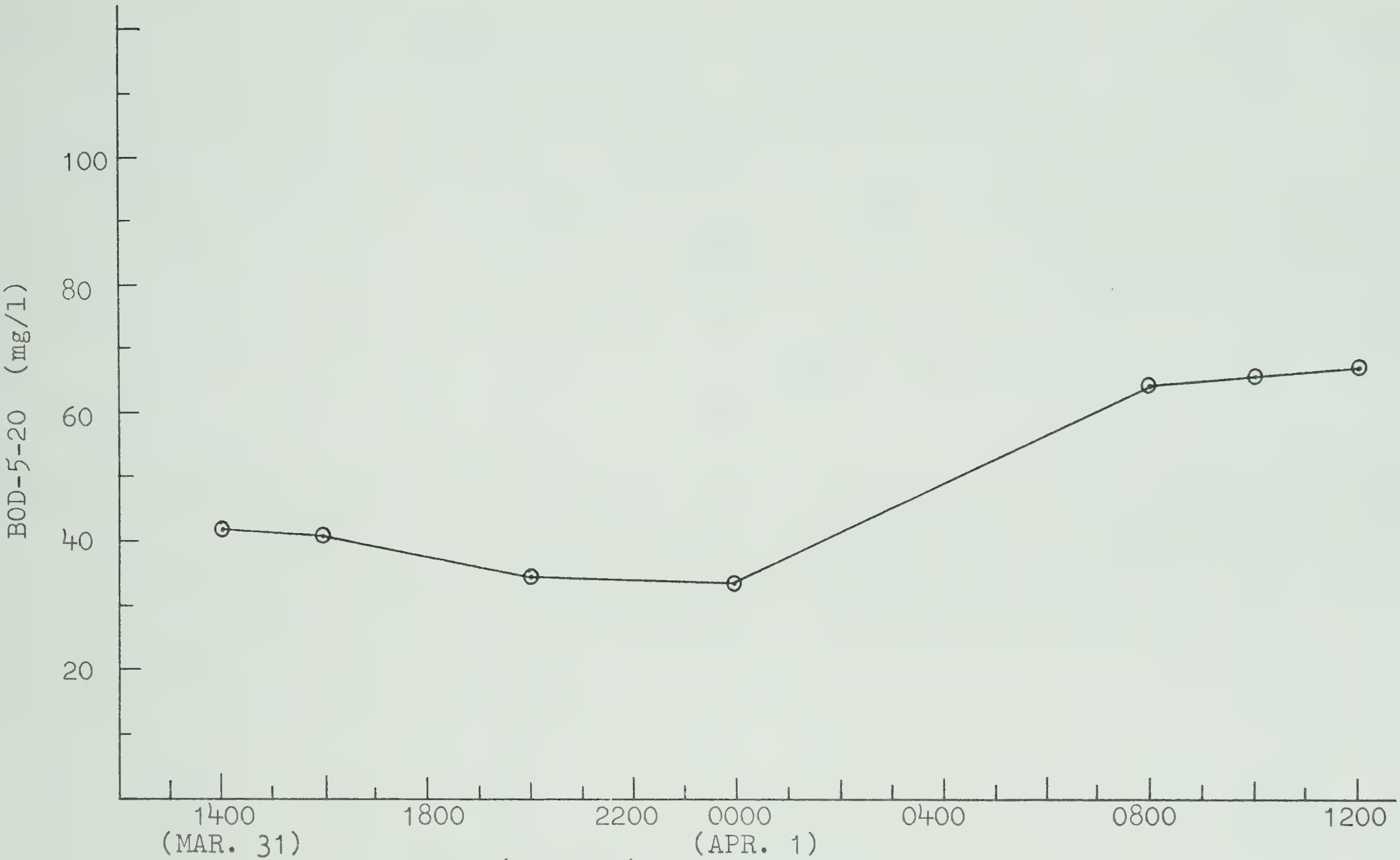

FIGURE III-XI DAILY VARIATION OF BOD OF SEWAGE EFFLUENT AT THE CITY OF RED DEER ON MARCH 31 TO APRIL 1, 1972

(i) Results of Sampling at the City of Red Deer Sewage Treatment Plant during the Survey

BOD results of sampling at the sewage treatment plant during the survey are listed in TABLE III-XI. TABLES III-III and III-X show the daily variations in BOD of the sewage effluent during two separate 24-hour periods.

BOD results and suspended solids results from sampling done by the City of Red Deer are tabulated in TABLE D-I, and average daily sewage flows determined by the city for each week between September 28, 1971 and March 21, 1972 are tabulated in TABLE D-II. Daily variations in sewage flow and DO of the sewage effluent, also determined by the city, are tabulated in TABLE D-III.

As is shown in TABLES III-III, III-X, and III-XI, the coefficients of variation were calculated for the samples. For the determination of the BOD-5-20 of a sample of sewage effluent, eight to twelve duplicates were used. A coefficient of variation was calculated from the results of each set of duplicates.

TABLE III-XI

BOD RESULTS OF SAMPLES OF SEWAGE EFFLUENT

FROM THE CITY OF RED DEER SEWAGE TREATMENT PLANT

Date	Time	Mean BOD-5-20*	Coefficient of Variation
Dec. 30, 1971	0900 hrs.	70.6mg/1	10.87%
Jan. 11, 1972	1400	70.6	13.51
Feb. 2	0900	77.2	11.42
Feb. 15	1000	106.2	1.45
Feb. 29	1000	118.6	7.75
Mar. 15	1000	89.8	11.85
Mar. 16	0900	73.0	7.49
Mar. 31	1400	42.0	6.98
Apr. 1	1000	65.5	9.37

*Grab samples

5. Analysis of Results

The data from the various sources was used in an attempt to correlate the drop in DO concentrations with the BOD loadings caused by the discharge of sewage effluent at the city.

(a) River flow data

Simpson (1971) mentioned that the 1% flow was 178 c.f.s. (i.e. this flow could be expected to occur 3 or 4 days a year). This statement was based on data recorded between 1956 and 1971. TABLES C-III and C-IV, which give the daily discharges of the river during the period from September, 1971 to March, 1972, show that the flow rate was equal to

or less than 175 c.f.s. on 40 days during the winter. The lowest daily flow measured during this time was 70 c.f.s. on March 6, 1972, as compared to the previous record low of 102 c.f.s.

(b) BOD data

At the outset of the survey it was decided that, since Standard Methods (1971) does not state clearly whether or not river samples should be seeded for BOD determinations, both seeded and unseeded BOD tests would be done for each sample. During the survey two seeded and two unseeded BOD tests were usually done on each river sample; in a few cases more than two seeded and unseeded tests were made, and in other cases only one of each type of test was made. Corrections for the seed (10 drops of fresh sewage effluent from the City of Red Deer Sewage Treatment Plant) were made on the results from the seeded tests, and then the corrected values were compared with the results from the unseeded BOD tests. Because only four tests were usually done on each sample, a statistical comparison of the results from the seeded and unseeded tests was considered questionable. Therefore, only a very simple comparison of the tests was attempted.

The results of the seeded and unseeded BOD-5-20 tests are listed in TABLES A-I to A-VIII. As is shown in these tables the seeded BOD tests appeared in most cases to give higher values than the unseeded tests. Examination of the

BOD data for the 67 river samples, on which both seeded and unseeded BOD tests were made, showed that the seeded tests gave the highest BOD value in 44 of the 67 cases: in 26 of the 44 cases all the seeded results were higher than the unseeded results. In only 23 cases did the unseeded tests give the highest value, and in 12 of the 23 cases all the unseeded results were higher than the seeded BOD results.

Further examination of the results showed that for the samples obtained from the upstream sites (-61.5 miles to 0.0 miles) the seeded BOD tests gave higher values than the unseeded tests in 12 of 19 cases: in 8 of the 12 cases all seeded results were higher than the unseeded results. For the downstream sampling sites (0.0 miles to +50.6 miles) the seeded tests gave higher values than the unseeded tests in 24 of 37 cases: in 12 of the 24 cases all seeded results were higher than the unseeded results. For the samples obtained from the tributaries (Medicine River, Little Red Deer River, and Blindman River) the seeded tests gave higher values than the unseeded tests in 8 of 11 cases: all seeded results were higher than unseeded results in 6 of the 8 cases. It is apparent from the data that, for about 2/3 of the 67 samples, seeding the BOD bottle tests resulted in higher BOD results.

For unseeded BOD tests to be successful, it is necessary that a sufficient number of microorganisms be present in the water sample. Lower numbers of micro-

organisms would likely be present upstream of the sewage outfall than downstream of the sewage outfall and, therefore, the upstream samples could be expected to show much more erratic results for the unseeded BOD tests than the downstream samples. However, the upstream BOD data does not appear to be more erratic than the other BOD data. Results of government sampling during 1971-72 at five sampling locations (these results are listed in Appendix B) did not show that there were larger populations of microorganisms in the downstream section, and in fact did show larger standard plate counts for the upstream section than the downstream section. Simpson (1971) showed that the average standard plate count per ml during the 1970-71 survey was 913 at Sundre, 3020 west of Bowden, 3653 at Highway 54, 1005 at the City of Red Deer, 42738 at the Burbank site, 26239 at Joffre Bridge, and 22531 at the Nevis gas plant. Therefore, the 1970-71 survey indicated that downstream populations of microorganisms were larger than the upstream populations.

Due to the more erratic results obtained from the unseeded BOD tests, the vaules from the seeded BOD tests were used in all of the tables, graphs, and calculations that are included in this chapter.

(c) DO data

As the DO data in TABLES A-I to A-VIII show, the agreement in results between duplicate DO tests was good

in most cases. In other cases, such as the Fevruary 2 sample from the Blindman River, difficulties in sampling caused greater deviations in DO results: in the aforementioned case, a problem arose because the river was not deep enough to completely immerse the DO sampling can. Other problems were caused by occasional sub-zero weather.

(d) Data from the City of Red Deer Sewage Treatment Plant

Using the data in TABLE III-XI and in Appendix D, the approximate river loading caused by the city's sewage effluent was calculated and tabulated in TABLE III-XII. The sewage plant's efficiency of removal of BOD and also of suspended solids was calculated using the data in TABLE D-I and then tabulated in TABLE III-XIII.

It should be noted that the city presently takes BOD samples from the plant once a week. TABLE III-X, which gives the results of seven BOD samples taken during 24 hours, shows that during 8 hours on April 1 the effluent's BOD increased from 33 mg/l to 64.2 mg/l. If the sewage effluent's BOD could vary as much as this during 8 hours, then such a variation could also have occurred on the sampling days; therefore, one sample taken once a week does not really give a true indication of the BOD of the sewage effluent unless it is known what daily variations are occurring in relation to this value. TABLE III-XII shows that on February 2 a sample which had been obtained by the city had a BOD of 193 mg/l, while a sample taken for this investigaton had a BOD

TABLE III-XII

APPROXIMATE BOD LOAD TO THE RED DEER RIVER FROM

THE CITY OF RED DEER SEWAGE TREATMENT PLANT

Date	Sewage Flow	BOD-5-20	Loading (lbs. DO/day)
Dec. 8*, 1971	2.36mgd	41mg/1	968
Dec. 22*	2.24	124	2778
Dec. 30	2.24	76.0	1702
Jan. 11, 1972	2.41	70.6	1701
Jan. 27*	2.56	145	3712
Feb. 2*	2.56	193	4941
Feb. 2	2.56	77.2	1976
Feb. 9*	2.59	126	3263
Feb. 15	2.59	106.2	2751
Feb. 16*	2.62	100	2620
Feb. 23*	2.54	94	2388
Feb. 29	2.54	118.6	3012
Mar. 1*	2.57	122	3135
Mar. 8*	2.68	111	2975
Mar. 15*	2.81	75	2108
Mar. 15	2.81	89.8	2523
Mar. 16	2.81	73.0	2031
Mar. 22*	2.81**	57	1602
Mar. 29*	2.81**	59	1658
Mar. 31	2.81**	39.1	1180
Apr. 1	2.81**	57.4	1841

* Sample obtained by the City of Red Deer.

** The sewage flow data for these dates was not available, and, therefore, the flow was assumed to be 2.81 mgd.

TABLE III-XIII

EFFICIENCY OF REMOVAL OF BOD AND SUSPENDED SOLIDS AT THE CITY OF RED DEER SEWAGE TREATMENT PLANT

Date	% Removal of BOD	% Removal of T.S.S.*
Dec. 8, 1971	93.2%	89.9%
Dec. 22	81.2	89.3
Jan. 27, 1972	73.7	56.6
Feb. 2	76.8	66.3
Feb. 9	76.0	50.7
Feb. 16	68.0	24.8
Feb. 23	83.6	42.5
Mar. 1	80.5	56.2
Mar. 8	79.2	74.8
Mar. 15	86.0	46.6
Mar. 22	88.6	82.1
Mar. 29	85.5	72.5

*T.S.S. is Total Suspended Solids.

of 77.2 mg/1. It is not known at what time the city's sample was taken so, therefore, this large difference in results of the two samples cannot be explained.

When looking at the sewage treatment plant's efficiency of removal of BOD and solids (tabulated in TABLE III-XIII), it should be remembered that in many ways this data is of limited value. The detention time of sewage in the plant is approximately 3 days and, since the weekly influent and effluent samples are taken on the same day, the original influent BOD of the sewage leaving the plant

at the time of sampling is not really known.

(e) Cross Sections at the Burbank Site

The cross sections which were taken of the Red Deer River at the Burbank site showed that an appreciable difference can occur in DO and BOD across a 60 yard width of river. TABLE III-IV shows DO levels ranging from 6.32 to 6.52 mg/1, and a BOD range of 0.64 to 3.32 mg/1; TABLE III-VII shows a DO range of 5.76 to 6.68 mg/1, and a BOD range of 3.36 to 3.98 mg/1; and TABLE III-VIII shows DO ranges of 6.70 to 7.90 mg/1 and of 7.05 to 8.00 mg/1, and BOD ranges of 2.57 to 3.16 mg/1 and of 3.00 to 3.64 mg/1. Variation such as shown by these cross sections can cause problems in obtaining a representative sample in order to study oxygen depletion along a river.

Another example of an unrepresentative DO sample is shown in TABLE B-IV. A government sample was obtained the February 15 sample only a minute or two before the sample, that is shown in TABLE III-IV for Joffre Bridge; but the government result of 9.60 mg/1 was much higher than the result of 6.34 mg/1 shown in TABLE III-VI. The cause of the difference in results stemmed from the fact that there were three layers of ice with water flowing below each layer and also over the top layer. When a hole was chopped through the three ice layers, the upper water layers were suddenly sucked down under the bottom ice layer. After the government DO sampler had been placed in the hole, a

large vortex formed and sucked air bubbles downward to the DO sampler. This occurrence was avoided as much as possible for the samples taken for this investigation.

(f) The Little Red Deer, the Medicine, and the Blindman Rivers

The limited sampling of the three main tributaries of the Red Deer River showed some of the conditions that are present in the rivers before their confluence with the Red Deer River.

During the winter of 1971-72, the Little Red Deer River at Red Lodge Provincial Park exhibited little noticeable flow. Because the river had thick ice at the sampling site, sampling was difficult and thus little information was obtained concerning this river. However, a relatively high BOD-5-20 value was obtained from analysis of the samples.

The samples obtained from the Medicine River at Highway 54 yielded some information. This river had consistently low DO levels during the winter of 1971-72, and this shown in the results listed in TABLE A-VIII (page A8) which show that the DO concentration was below 1.08 mg/1 on four of the six sampling days. The lowest DO reading of the survey was obtained for a sample obtained from the Medicine River on February 2. BOD samples showed the river to have only a slightly higher oxygen demand compared to many of the upstream sampling sites on the Red Deer River. However, TOC samples showed the Medicine River to have fairly high

inorganic carbon and organic carbon concentrations. This river had probably a larger flow than either of the other two tributaries, but this cannot be confirmed because there is no available flow data on the three tributaries.

Simpson (1971) stated that approximately 2 mg/1 of DO were removed from the Red Deer River just after the confluence of the Little Red Deer River and the Medicine River. Results of the 1971-72 survey showed that the DO levels at the Highway 54 Bridge, which is 9 to 10 miles downstream of the point of confluence of the two tributaries with the Red Deer River, were often less than 75% of the saturation value of 13.5 mg/1 (at $0^{o}C$, and at 2200 ft above sea level). Government sampling at the site 20 miles west of Bowden showed that the DO levels 26 miles upstream of the point of confluence were often more than 90% of the saturation value.

The Blindman River had higher DO levels and lower BOD levels than the Medicine River. The water from this river had only a slight color while the Medicine River's water had a much darker color. The Blindman River showed a wide range of organic carbon and inorganic carbon concentrations.

All three of the tributaries have their origins in muskeg areas, and all three also flow through farm areas. Thus they have high organic carbon and BOD levels plus low DO levels. The Medicine River, which is slower, more sluggish, but larger in size than the other two rivers, has characteristics which prevent much physical reaeration in the river during the winter; thus the DO levels in this

river drop much lower than in the other two tributaries. The Blindman River, which is shallower, smaller in size, but faster than the other two rivers, has characteristics which enable some physical reaeration to occur in the river during the winter.

(g) Oxygen Depletion as Related to Removal of BOD in the Red Deer River

Bouthillier and Simpson (1972) found that on January 20, 1971 the oxygen used in the 50 miles of river between the City of Red Deer and the Nevis gas plant was 2.7 times the drop in BOD-5-20, and also mention that studies of the North Saskatchewan River have determined that the drop in DO during 20 miles of river was approximately 33% of the drop in BOD. It was theorized that the difference between the two rivers appeared to result from the type of BOD removal, in that much of the BOD in the North Saskatchewan River was removed by sedimentation in the first 20 miles of river immediately downstream of the City of Edmonton sewage outfall. In the Red Deer River this did not appear to occur, but what does happen is not really known.

An attempt was made in this investigation to confirm the ratio of 2.7. Because for the major portion of the winter of 1971-72 there was an open stretch of water at the Joffre Bridge, and because no attempt was made to ascertain how much aeration took place in this stretch of river, it was difficult to determine exactly how much

oxygen was used in the river between the city and the gas plant. However, the ratio of oxygen used to BOD removed was calculated for the 50 miles of river by neglecting the aeration at the Joffre Bridge. The ratio was also calculated for the 20.5 miles of river between the sewage outfall and the Joffre Bridge. The results of the calculations are tabulated in TABLES III-XIV to III-XVI.

The theoretical river BOD at the sewage outfall was calculated by using the formula

$$\text{River BOD} = \frac{(\text{river flow} \times \text{BOD at RD}) + (\text{sewage flow} \times \text{sewage BOD})}{\text{river flow} + \text{sewage flow}}$$

When the DO of sewage effluent was not known (see TABLES D-III and D-IV), the sewage DO was assumed to be 0mg/1.

TABLE III-XIV

OXYGEN USE IN THE RED DEER RIVER

DOWNSTREAM OF THE CITY'S SEWAGE OUTFALL

Date	River DO* at outfall (mg/1)	DO used in 20.5 miles (mg/1)	DO used in 50.0 miles (mg/1)
Dec. 28-30	9.40	4.97	--
Jan. 11	8.32	4.67	--
Feb. 1-2	9.00	5.29	8.62
Feb. 15	9.10	2.76	4.65
Feb. 16	9.12	3.00	--
Feb. 29	7.97	4.22	7.09
Mar. 1-2	8.58	5.76	7.84
Mar. 15	9.93	6.01	--
Mar. 16	10.08	5.50	--

*The river DO at the city's sewage outfall was calculated by using the formula on page 65

The river's theoretical DO at the sewage outfall was calculated by using the formula

$$\text{River DO} = \frac{(\text{river flow} \times \text{DO at RD}) + (\text{sewage flow} \times \text{effluent DO})}{\text{river flow} + \text{sewage flow}}$$

The results listed in TABLE III-XVI show that the oxygen used in the 20.5 miles of river between the sewage outfall and Joffre Bridge was an average of 4.22 times the

TABLE III-XV

BOD REMOVAL IN THE RED DEER RIVER

DOWNSTREAM OF THE CITY'S SEWAGE OUTFALL

(All BOD values are BOD-5-20 values)

Date	Sewage BOD (mg/1)	River BOD* at outfall (mg/1)	BOD drop in 20.5 miles** (mg/1)	BOD drop in 50.0 miles** (mg/1)
Dec. 28-30	76.0	3.32	-0.08	----
Feb. 1-2	77.2	3.36	+0.62	-0.72
Feb. 1-2***	193.0	6.05	+3.31	+1.97
Feb. 15	106.2	3.72	+1.33	+2.90
Feb. 16***	100.0	4.45	+3.16	----
Feb. 29	118.6	5.99	+4.46	+3.78
Mar. 1-2***	122.0	6.40	+4.17	+4.48
Mar. 15	89.8	3.88	+0.48	----
Mar. 15***	75.0	3.58	+0.18	----
Mar. 16	73.0	3.32	+0.96	----

* The river BOD at the sewage outfall was calculated by using the formula on page 64.

** Increases in the river BOD between the sewage outfall and the two downstream sites are tabulated as negative values.

***These sewage BOD's are taken from TABLE D-I.

removal of BOD-5-20, and that the oxygen used in the 50.0 miles of river between the sewage outfall and the Nevis gas plant was an average of 2.40 times the removal of BOD-5-20. The latter ratio of 2.40 agrees fairly well with the ratio of 2.7 which Bouthillier and Simpson (1972) obtained for the 50.0 miles downstream of the city's

TABLE III-XVI

RATIO OF OXYGEN USED TO BOD-5-20 REMOVED IN THE RED DEER RIVER DURING THE SURVEY

Date	Ratio for the first 20.5 miles downstream of outfall	Ratio for the first 50.0 miles downstream of outfall
Dec. 28-30	-62.12	----
Feb. 1-2	+8.53	-11.97
Feb. 1-2*	+1.60	+4.37
Feb. 15	+2.08	+1.60
Feb. 16*	+0.95	----
Feb. 29	+0.94	+1.90
Mar. 1-2*	+1.38	+1.75
Mar. 15	+1.25	----
Mar. 15*	+33.40	----
Mar. 16	+5.73	----
Average**	+4.22	+2.40

* Values for the sewage BOD's on these days were taken from TABLE D-I.

**The average ratio for the first 20.5 miles did not include the values of -62.12 and 33.40, and the average ratio for the first 50.0 miles did not include the value of -11.97.

sewage outfall. An approximate ratio of 2.5 for the first 20 miles downstream of the sewage outfall was obtained from the data in FIGURE V of Bouthillier and Simpson (1972). In calculating the average values of the ratios in TABLE III-XVI, the value of -62.12 for December 28-30 and the value of 33.40 for March 15 were not included in the calculation of the average ratio for the first 20.5 miles because these values were unreasonable. Similarly, the value of -11.97 for February 1-2 was not included in the calculation of the average ratio for the first 50.0 miles downstream of the city's sewage outfall.

The ratios were all calculated by using the BOD-5-20 results. To extrapolate a BOD-5-20 value to its theoretical BOD-5-0 value, the BOD-5-20 was multiplied by a factor of 0.6 (obtained from Equation 4-11 in Rich (1963)). Therefore, it can be observed that, since the BOD-5-0 removed was smaller than the BOD-5-20 removed, the ratio of DO use to BOD-5-0 removal was about 1.7 times greater than the ratio of DO use to BOD-5-20 removal.

(h) Oxygen Depletion as Related to Removal of TOC

Bouthillier and Simpson (1972) reported that the drop in DO between the sewage outfall and the gas plant was approximately equal to the drop in TOC, and data from the same report indicated that the drop in DO between the sewage outfall and Joffre Bridge was approximately 75% of the drop in TOC. TABLES III-XVII and III-XVIII show the

comparison of oxygen used to TOC removed on seven sampling days during the winter of 1971-72. The ratios in TABLE III-XVIII were calculated in the same way as the ratios of oxygen used to BOD-5-20 removed in TABLE III-XVI. Unfortunately, TOC data on the city's sewage effluent were not obtained during the investigation and, therefore, a TOC value of 100 mg/1 for the sewage effluent was used in the calculations; Bouthillier and Simpson (1972) included BOD and TOC data on the sewage effluent, and the figure of 100 mg/1 was obtained from this data. The approximate value of 100 mg/1 is the probable source of much of the variation of the ratios in TABLE III-XVIII. However, it

TABLE III-XVII

TOC REMOVAL IN THE RED DEER RIVER

DOWNSTREAM OF THE CITY'S SEWAGE OUTFALL

Date	River TOC* at outfall (mg/1)	TOC drop in 20.5 miles (mg/1)	TOC drop in 50.0 miles (mg/1)
Feb. 15	5.1	-1.9	+0.1
Feb. 16	8.2	+5.2	--
Feb. 29	6.5	+3.5	-0.5
Mar. 1	12.6	+5.6	--
Mar. 2	12.9	-14.1	+8.9
Mar. 15	7.9	-0.1	--
Mar. 16	12.8	+4.8	--

*The river TOC at the city's sewage outfall was calculated by using a value of 100 mg/1 for the TOC of the sewage effluent, and by using a formula similar to those on pages 64 and 65.

should also be noted that the TOC results during the investigation exhibited a somewhat erratic behaviour, and this was also a big factor in causing wide variation in the values of the ratios. The TOC results would have probably been much more consistent if more than one TOC sample had been obtained at each sampling hole. The unreasonable TOC values, which were obtained at some sampling points on various occasions, might easily be discarded if, for example, such a value was to be found for only one of three samples obtained from a sample hole on a sampling occasion.

TABLE III-XVIII

RATIO OF OXYGEN USED* TO TOC REMOVED

IN THE RED DEER RIVER DURING THE SURVEY

Date	Ratio for the first 20.5 miles downstream of outfall	Ratio for the first 50.0 miles downstream of outfall
Feb. 15	-1.45	+46.50
Feb. 16	+0.58	----
Feb. 29	+1.20	-14.18
Mar. 1	+1.03	----
Mar. 2	-0.41	+0.88
Mar. 15	-60.10	----
Mar. 16	+1.14	----
Average**	+0.50	+0.88

* Values of oxygen used were obtained from TABLE III-XIV.

**In calculating the average ratios, the values of -0.41 and -60.10 for Joffre Bridge and the values of +46.50 and -14.18 for the Nevis gas plant were not included.

TABLE III-XVIII shows that the average ratio of oxygen used to TOC removed was 0.50 for the 20.5 miles between the sewage outfall and Joffre Bridge, and for the 50.0 miles between the sewage outfall and the Nevis gas plant the average ratio was 0.88. The latter average was obtained from only one value because the value of +46.50 for February 15 and the value of -14.58 for February 29 were not included in the average ratio for the first 50.0 miles downstream of the city's sewage outfall; these two values were considered unreasonable. In calculating the average ratio for the first 20.5 miles, the value of -60.10 for March 15 and the value of -0.41 (obtained from a TOC value of 27 mg/1 at Joffre Bridge) for March 2 were not included because these two values were also considered unreasonable.

CHAPTER IV

CONCLUSIONS

The original purpose of this investigation was to determine the dissolved oxygen concentrations and oxygen demands in the Red Deer River at various sampling points in order that the effects of operation of the U-tube aerator could be observed. Because the installation of the U-tube aerator was completed only a week before the ice cover on the river broke up, and because at that time there was already much physical reaeration occurring in the stretches of open water on the river, sampling results could confirm only that the aerator at partial operation was increasing the DO levels of the water, which was passing through it, by 1 to 2 mg/1. No other effects of operation of the aerator could be accurately determined.

The main purpose of the investigation was modified to a limited analysis of the oxygen depletion under ice cover in the Red Deer River during the first 50 miles downstream of the sewage outfall at the City of Red Deer. In order to achieve this objective, the conditions in the river upstream of the city had to be determined.

The type of analyses made during the survey included the DO, BOD-5-20, TOC, and COD tests. The COD results

proved to be too erratic and thus were discarded. The DO test and the BOD-5-20 test provided the most useful results. Both seeded and unseeded BOD tests were made on most of the samples. With the river water samples, the seeded BOD tests in 44 of 67 cases gave higher values than the unseeded BOD tests. Unfortunately, it was not possible to obtain larger volumes of water samples in order to make more than four BOD tests on each water sample. In order to use the statistical measures of standard deviation and coefficient of variation, a larger number of test results for each sample would have been more desirable. Therefore, a thorough statistical comparison of the seeded and unseeded BOD test results was not attempted. However, from a simple visual comparison of the seeded and unseeded test results, it was decided that the seeded BOD test probably gave more reliable results than the unseeded BOD test.

The Red Deer River at the sampling point which was 61.5 miles upstream of the sewage outfall had DO levels at about 90% of the saturation value of 13.5 mg/l, and also relatively low BOD levels during much of the winter of 1971-72. However, the Red Deer River at Highway 54, which is 23.5 miles upstream of the city's sewage outfall, had DO levels at only 63% to 80% of the saturation value. This decrease in DO was equal to the removal of as much as 2 mg/l of DO, and at least part of

this amount was removed by the addition of the flows from the Little Red Deer River and the Medicine River at a point 10 to 12 miles upstream of the Highway 54 Bridge. The Medicine River was shown to be a river of low DO, relatively high BOD, and high inorganic carbon and organic carbon concentrations.

From Highway 54 to the City of Red Deer, dissolved oxygen and oxygen demand levels did not appear to change significantly.

Sewage effluent at the City of Red Deer was discharged at a rate of approximately 2.5 mgd during the winter. During the period from December 8, 1971 to April 1, 1972, an average BOD-5-20 value of 93.3 mg/1 was obtained; the maximum value was 193 mg/1.

Between the city and the Burbank site, which is 7.5 miles downstream of the city's sewage outfall, a drop of 2 to 4 mg/1 of DO was found, and an increase in BOD was also noted. The only discharge of effluent in this stretch of river was the discharge of sewage effluent at the city, and the effluent must have caused almost all the DO decrease and BOD increase.

Downstream of the Burbank site is the point of confluence of the Blindman River with the Red Deer River. The Blindman River was another tributary which was characterized by low DO levels and relatively high inorganic carbon and organic carbon concentrations during the winter.

However, its BOD levels appeared to be low. Little information was available concerning flow rates of this river as well as the other two tributaries and, therefore, it was difficult to determine the effects of this river and the other two tributaries on the DO and BOD levels of the Red Deer River.

At the Joffre Bridge aerator site, the DO levels of the Red Deer River were usually 5 to 7 mg/1 below those at the city. The average ratio of oxygen used to theoretical removal of BOD-5-20 in the 20.5 miles of river between the site and the sewage outfall was 4.22, which was not very close to the value of 2.5 obtained from a previous study. During the winter some aeration occurred in an open stretch of water at the aerator site, and the slight increase in DO was occasionally observed at a farm which is 9 miles downstream of the Joffre Bridge.

At the Nevis gas plant, 50 miles downstream of the city's sewage outfall, DO levels as low as 0.38 mg/1 were recorded. The average ratio of oxygen used to theoretical BOD-5-20 removal in the 50 miles of river upstream of the site was 2.40 which agreed relatively well with the value of 2.7 obtained in a previous study.

A comparison of the oxygen used to TOC removed showed ratios of 0.50 for the first 20.5 miles and 0.88 for the first 50 miles downstream of the city's sewage outfall. However, since the data used were sometimes in-

complete or inconsistent, these ratios are not necessarily reliable numbers.

In assessing the oxygen demand in a river, there is as yet no reliable test that can indicate the exact amount of oxygen required for the biological oxidation of the organic material present in the river. The BOD-5-20 test can indicate the relative amount of oxygen required, but it does not duplicate stream conditions and thus does not show the exact amount of oxygen required or the exact rate of use; the BOD-5-20 test also shows only about 68% of the first stage BOD at 20°C, and does not show the oxygen required for the nitrification stage of the biochemical decomposition of organic material. Furthermore, problems stemming from the sampling conditions and technique can result in misleading sampling results. Therefore, an assessment of oxygen depletion under ice cover in a river has many definite limitations when tests such as the DO, BOD, and TOC tests are used to carry out the assessment. The absence of any biological surveys during the investigation also places a few limitations on such an assessment. It is possible, however, to form some conclusions from this survey.

During the winter of 1971-72 the Red Deer River under ice cover had DO levels of 8 to 11 mg/1 at the City of Red Deer. Addition of sewage effluent at the City of Red Deer caused a sudden drop in DO in the first 20 miles

downstream of the sewage outfall. The high BOD of the city's sewage effluent and the extremely low flows of the Red Deer River during the winter combined to cause a drastic removal of DO in the first 50 miles, and DO levels at the Nevis gas plant occasionally approached anaerobic conditions. Without physical reaeration which occurred at the Joffre Bridge and also downstream of the Nevis gas plant, dissolved oxygen levels in the river would probably have been much lower.

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APPENDIX A

DETAILED DATA FROM SAMPLING DURING SURVEY

TABLE A-I DATA FROM RED DEER RIVER SAMPLES DURING DECEMBER, 1971 TO APRIL, 1972

-- MILE -61.5 TO MILE -18.0 *

Sampling Location	Date	DO	BOD-5-20 (seeded)	BOD-5-20 (unseeded)	TOC	Tot. Inorganic Carbon
-61.5 miles	Mar. 15	12.10	2.78	2.03	3	22
		12.00	2.20	2.54		
-23.5 miles	Dec. 30	10.43	2.12	1.94	--	--
		10.48	1.99	1.96		
		10.42				
	Feb. 2	8.01	2.12	1.92	--	--
		9.11				
	Feb. 15	9.75	3.18	2.98	4	27
			2.92	2.89		
	Mar. 1	9.10	4.40	4.56	5	23
		9.30	3.64	2.99		
	Mar. 2	9.41	--	--	3	36
		9.55				
	Mar. 15	10.79	1.97	1.57	8	38
		11.11	1.95	1.66		
	Mar. 16	10.88	2.27	1.80	6	29
		10.60	1.70	1.76		
	Apr. 1	11.09	2.16	2.01	--	--
		10.54	2.09	2.21		
			2.28	2.02		
			2.18	2.34		
			2.06	2.14		
-18.0 miles	Mar. 16	10.85	2.98	2.43	8	32
		10.54	2.40	2.16		
	Apr. 1	10.00	3.22	3.40	--	--
			3.27	3.44		

All results are in units of mg/l.

* See TABLE III-I and FIGURE III-I for description of the sampling locations.

TABLE A-II DATA FROM RED DEER RIVER SAMPLES DURING DECEMBER, 1971 TO APRIL, 1972

-- MILE -4.5 TO MILE 0.0

Sampling Location	Date	DO	BOD-5-20 (seeded)	BOD-5-20 (unseeded)	TOC	Tot. Inorganic Carbon
-4.5 miles (r)	Dec. 28	9.63	1.73	1.63	--	--
		9.60	1.71	1.69		
		9.63				
	Feb. 1	9.21	1.60	1.38	--	--
		9.37				
	Feb. 15	9.17	1.30	1.11	3	25
		9.20	1.61	0.93		
	Feb. 16	9.19	2.20	0.80	6	32
		9.26	2.18	0.93		
	Feb. 29	8.17	2.98	2.00	4	32
			3.07	2.88		
	Mar. 1	8.68	--	--	10	30
		8.79				
-4.5 miles (w)	Jan. 11	8.15	--	--	--	--
		8.25				
	Feb. 1	7.91	--	--	--	--
		8.01				
	Mar. 15	10.14	2.06	1.95	6	34
		10.03	2.10	2.12		
	Mar. 16	10.18	1.81	1.95	11	36
		10.26	1.91	2.01		
	Apr. 1	10.57	2.57	2.60	--	--
			2.46	2.27		
0.0 miles	Jan. 11	8.61	--	--	--	--
		8.51				
	Feb. 1	9.51	0.74	0.96	--	--

All results are in units of mg/1.

TABLE A-III DATA FROM RED DEER RIVER SAMPLES DURING DECEMBER, 1971 TO APRIL, 1972

-- MILE +7.5

Sampling Location	Date	DO	BOD-5-20 (seeded)	BOD-5-20 (unseeded)	TOC	Tot. Inorganic Carbon
+7.5 miles *	Jan. 11					
Hole #1		6.48	--	2.24	--	--
		6.56				
Hole #2		6.44	--	3.32	--	--
		6.38				
Hole #3		6.40	--	1.80	--	--
		6.38				
Hole #4		6.38	--	2.12	--	--
		6.42				
Hole #5		6.28	--	0.64	--	--
		6.36				
+7.5 miles **						
Hole #1	Feb. 16	6.61	2.12	1.61	5	31
		6.58	1.90	1.50		
	Mar. 1	5.79	4.00	4.06	6	43
		5.73	3.97	4.06		
	Mar. 15	6.81	2.79	2.63	23	38
		6.60	2.93	2.80		
	Mar. 16	7.05	3.59	3.41	10	33
		7.05	3.56	3.86		

All results are in units of mg/1.

* Hole #1 was approximately 10 yds from the river's north bank: the other holes were at intervals of approximately 10 yds starting at Hole #1. Hole #5 was approximately 10 yds from the river's south bank.

** Hole #1 was approximately 15 yds from the river's north bank, Hole #2 was about 15 yds south of Hole #1, and Hole #3 was approximately 15 yds south of Hole #2.

TABLE A-IV DATA FROM RED DEER RIVER SAMPLES DURING DECEMBER, 1971 TO APRIL, 1972

-- MILE +7.5 TO MILE +20.5

Sampling Location	Date	DO	BOD-5-20 (seeded)	BOD-5-20 (unseeded)	TOC	Tot. Inorganic Carbon
+7.5 miles * Hole #2	Feb. 16	6.11	1.60	1.58	4	22
		6.89	1.76	1.49		
	Mar. 1	6.32	3.42	3.75	7	37
		6.41	3.30	3.16		
	Mar. 2	6.01	--	--	5	38
		6.19				
	Mar. 15	6.66	2.74	2.26	6	34
		7.41	2.40	2.58		
	Mar. 16	7.76	3.08	3.11	5	35
		7.78	2.92	3.24		
Hole #3	Mar. 1	6.66	--	--	7	38
		6.71				
	Mar. 15	8.09	3.40	2.88	6	31
		7.72	2.93	3.16		
	Mar. 16	7.96	2.59	3.72	6	37
		8.04	3.68	3.84		
+20.5 miles	Dec. 28	4.41	3.36	3.03	--	--
		4.46	3.43	3.11		
		4.42				
	Jan. 11	3.65	1.30	1.64	--	--
	Feb. 1 (1100hrs)	3.73	6.55	5.59	--	--
	Feb. 1 (1630hrs)	3.71	2.74	3.04	--	--

All results are in units of mg/l.

* Hole #1 was approximately 15 yds from the river's north bank, Hole #2 was about 15yds south of Hole #1, and Hole #3 was approximately 15 yds south of Hole #2.

TABLE A-V DATA FROM RED DEER RIVER SAMPLES DURING DECEMBER, 1971 TO APRIL, 1972

-- MILE +20.5

Sampling Location	Date	DO	BOD-5-20 (seeded)	BOD-5-20 (unseeded)	TOC	Tot. Inorganic Carbon
+20.5 miles	Feb. 16	6.20	1.18	1.50	3	36
		6.03	1.40	1.11		
	Feb. 29	3.75	1.54	1.07	3	17
			1.52	1.16		
	Mar. 1	--	1.67	2.00	7	33
			1.78	1.70		
	Mar. 2	2.82	2.10	1.63	27	38
			2.36	1.77		
	Apr. 1	9.61	6.74	6.47	--	--
			6.54	6.30		
+20.5 miles -- intake	Mar. 15	4.14	3.48	3.18	8	42
		3.44	3.33	3.36		
		4.09				
		4.03				
	Mar. 16	4.47	2.55	2.27	14	38
		4.77	2.17	2.35		
		4.75				
		4.75				
		4.80				
		4.48				
		4.50				
		4.65				
		4.31				
		4.36				
	Mar. 17	5.14	2.43	2.47	8	31
		5.11	2.51	2.25		

All results are in units of mg/l.

TABLE A-VI DATA FROM RED DEER RIVER SAMPLES DURING DECEMBER, 1971 TO APRIL, 1972

-- MILE +20.5 TO MILE +29.5

Sampling Location	Date	DO	BOD-5-20 (seeded)	BOD-5-20 (unseeded)	TOC	Tot. Inorganic Carbon
+20.5 miles -- outlet	Mar. 15*	5.59	--	--	7	36
	Mar. 16*	6.39	--	--	8	36
		6.75				
		6.20				
		6.70				
		6.75				
		6.51				
		6.15				
		6.71				
		6.66				
		6.61				
	Mar. 17	5.16	--	--	--	--
		5.19				
		5.12				
+20.5 miles -- dam	Mar. 17	--	2.05	2.35	5	35
			2.25	2.25		
+29.5 miles	Feb. 29	4.99	4.30	4.36	5	29
			4.31	4.18		
	Mar. 1	2.41	--	--	4	42
	Mar. 16	9.20	2.95	2.97	6	31
		9.16	3.11	2.99		
	Mar. 17	6.95	1.78	1.88	5	38
		6.97	2.05	1.67		

All results are in units of mg/l.

TABLE A-VII DATA FROM RED DEER RIVER SAMPLES DURING DECEMBER, 1971 TO APRIL, 1972

-- MILE +40.5 TO MILE +50.6

Sampling Location	Date	DO	BOD-5-20 (seeded)	BOD-5-20 (unseeded)	TOC	Tot. Inorganic Carbon
+40.5 miles	Mar. 1	2.62	2.74	2.27	4	31
			2.29			
	Mar. 17	8.04	2.55	2.55	5	33
		8.01	2.72	2.61		
+50.0 miles	Feb. 1	0.38	4.08	2.09	--	--
	Feb. 15	4.49	0.77	0.79	5	32
		4.48	0.87	0.81		
		4.39				
	Feb. 29	0.88	2.85	1.87	7	32
			1.57	1.87		
	Mar. 2	0.70	1.89	1.77	4	37
		0.79	1.96			
	Mar. 17	7.62	2.49	2.45	10	38
		6.95	2.43	2.35		
+50.6 miles	Feb. 15	6.65	0.57	0.65	4	26
		6.63	0.81	0.64		
	Feb. 29	--	1.10	1.76	7	25
			1.34	1.61		
	Mar. 17	8.85	2.26	1.81	5	34
		8.65	1.80	1.90		
	Mar. 31	10.14	3.11	3.06	--	--
			3.17	2.87		

All results are in units of mg/l.

TABLE A-VIII DATA FROM SAMPLES TAKEN DURING DECEMBER, 1971 TO APRIL, 1972 FROM TRIBUTARIES OF THE RED DEER RIVER

Sampling Location	Date	DO	BOD-5-20 (seeded)	BOD-5-20 (unseeded)	TOC	Tot. Inorganic Carbon
Little Red Deer R.	Dec.29	6.13	3.70	3.20	--	--
		6.10	3.53	3.31		
		6.10				
	Feb. 13	--	3.78	--	--	--
			3.88			
			3.11			
			3.59			
			3.90			
Medicine R.	Dec. 30	4.17	2.45	2.28	--	--
		4.22	2.34	2.21		
		4.21				
	Feb. 2	0.32	1.34	1.27	--	--
	Feb. 15	0.84	2.19	1.93	9	62
		1.02	2.05	2.12		
	Mar. 1	0.97	2.97	2.85	16	61
			2.99			
	Mar. 15	1.12	2.64	2.62	8	73
		1.03	2.41	2.58		
	Apr. 1	8.06	5.06	4.99	--	--
			5.20	4.99		
Blindman R.	Feb. 2	2.95	0.88	1.33	--	--
		4.79				
	Feb. 16	4.00	0.66	0.33	6	104
		3.97	0.70	0.38		
	Mar. 1	3.85	1.67	1.43	8	91
		3.66	1.70	2.10		
	Mar. 15	5.63	1.65	1.28	28	51
		5.46	1.53	1.73		

All results are in units of mg/l.

APPENDIX B

DETAILED GOVERNMENT DATA FROM
SAMPLING DONE ON THE RED DEER RIVER
(DATA PROVIDED BY
THE DIVISION OF POLLUTION CONTROL,
THE DEPARTMENT OF THE ENVIRONMENT
OF THE PROVINCE OF ALBERTA)

TABLE B-I

GOVERNMENT DATA FOR THE SAMPLING SITE AT THE BRIDGE OVER THE RED DEER RIVER, 20 MILES WEST OF BOWDEN

	Nov.16,1971	Nov.30	Jan.5,1972	Feb.15
DO	13.4mg/1	12.9	11.1	12.1
BOD-5-20	0.5mg/1	0.7	0.8	0.3
Tot. Coliform*	350	240	40	---
E. coli*	14	0	17	---
Standard Plate Count**	500	550	1600	---
Temperature (^{o}C)	---	0.0	0.0	0.0
pH	8.2	8.2	8.1	7.9
Spec. Conductance***	---	---	---	390
Turbidity	1 JTU	1	1	1
Odor****	2.0	4.0	1.0	2.0
Tot. Alkalinity (mg/1 $CaCO_3$)	155.0	200.0	175.0	120.0
Tot. Hardness (mg/1 $CaCO_3$)	---	---	210.0	240.0
Ca (dissolved)	---	---	37.0mg/1	34.0
Mg (dissolved)	---	---	29.0mg/1	37.0
Tot. Ash Residue	174.0mg/1	234.0	304.0	320.0
Oil & Greases	1.4mg/1	0.4	2.3	---
Phenols	0.004mg/1	0.002	0.004	0.002
Nitrogen (nitrate & nitrite)	0.5mg/1	0.1	0.1	0.1
Nitrogen (diss. NH_3)	0.1mg/1	0.1	0.1	LT 0.1
Tot. Phosphate	0.8mg/1	0.0	0.1	LT 0.1
Sulphate (diss.)	---	65.0mg/1	65.0	50.0
Chloride (diss.)	---	2.0mg/1	---	32.0
Potassium (diss.)	0.6mg/1	0.6	1.0	---
Sodium (diss.)	4.0mg/1	7.0	4.0	---
Iron (diss.)	---	---	LT 0.1mg/1	LT 0.1

LT denotes "less than" when preceding a number.
* units of organisms/ml.
** units of organisms per 100 ml.
*** units of micromhos/cm.
****denotes Threshold Odor Number.

TABLE B-II

GOVERNMENT DATA FROM SAMPLING AT

THE CITY OF RED DEER WATER TREATMENT PLANT

	Nov.16,1971	Nov.30	Jan.5,1972	Feb.15
DO	13.2mg/1	12.8	9.0	10.0
BOD-5-20	2.1mg/1	1.2	0.7	2.4
Tot. Coliform*	17	2	140	---
E. coli*	5	0	0	---
Standard Plate Count**	10	1100	500,000	---
Temperature (^{o}C)	---	0.0	0.0	0.0
pH	8.3	8.4	7.9	7.9
Spec. Conductance***	420	---	---	430
Turbidity	15 JTU	9	2	1
Odor****	2.0	4.0	1.0	4.0
Tot. Alkalinity (mg/1 $CaCO_3$)	190.0	240.0	210.0	195.0
Tot. Hardness (mg/1 $CaCO_3$)	215.0	---	215.0	210.0
Ca (dissolved)	---	---	34.0	32.0
Mg (dissolved)	---	---	32.0	32.0
Tot. Ash Residue	344.0mg/1	352.0	336.0	---
Oil & Greases	1.2mg/1	0.4	1.3	---
Phenols	0.002mg/1	0.001	0.001	LT 0.001
Nitrogen (nitrate & nitrite)	0.3mg/1	0.1	0.1	0.2
Nitrogen (diss. NH_3)	0.1mg/1	0.1	0.1	LT 0.1
Tot. Phosphate	0.3mg/1	0.1	0.05	0.1
Sulphate (diss.)	40.0mg/1	55.0	65.0	35.0
Chloride (diss.)	4.0mg/1	3.0	1.0	2.0
Fluoride (diss.)	---	0.10mg/1	0.17	0.15
Potassium (diss.)	1.0mg/1	1.4	1.0	---
Sodium (diss.)	7.0mg/1	9.0	7.0	---
Iron (diss.)	---	---	LT 0.1	LT 0.1
Surfactants (mg/1)	---	---	---	LT 0.01

LT denotes "less than" when preceding a number.
* units of organisms/ml.
** units of organisms per 100 ml.
*** units of micromhos/cm.
****denotes Threshold Odor Number.

TABLE B-III

GOVERNMENT DATA FROM SAMPLING AT THE BURBANK SITE

	Nov. 16, 1971	Nov. 30
DO	16.6mg/1	14.2
BOD-5-20	3.2mg/1	1.6
Tot. Coliform*	79	170
E. coli*	2	0
Standard Plate Count**	2100	450
Temperature (°C)	---	0.0
pH	8.5	8.5
Turbidity	1 JTU	1
Odor***	2.0	4.0
Tot. Alkalinity (mg/1 $CaCO_3$)	185.0	230.0
Tot. Ash Residue	248.0	312.0
Oil & Greases	1.5mg/1	0.8
Phenols	0.002mg/1	0.001
Nitrogen (nitrate & nitrite)	0.1mg/1	0.1
Nitrogen (diss. NH_3)	0.5mg/1	0.4
Tot. Phosphate	0.5mg/1	0.7
Chloride (diss.)	---	6.0mg/1
Potassium (diss.)	1.1mg/1	1.7
Sodium (diss.)	11.0	11.0

* units of organisms/ml.
** units of organisms per 100 ml.
***denotes Threshold Odor Number.

TABLE B-IV

GOVERNMENT DATA FROM SAMPLING AT THE JOFFRE BRIDGE

	Nov.16,1971	Nov.30	Jan.5,1972	Feb.15
DO	14.6mg/1	14.1	4.3	9.6
BOD-5-20	1.1mg/1	1.3	0.7	0.5
Tot. Coliform*	8	49	170	---
E. coli*	0	0	24	---
Standard Plate Count**	60	800	220	---
Temperature (^{o}C)	---	0.0	0.0	0.0
pH	8.4	8.5	7.8	8.0
Spec. Conductance***	---	---	---	650
Turbidity	1 JTU	1	1	1
Odor****	2.0	4.0	4.0	4.0
Tot. Alkalinity (mg/1 $CaCO_3$)	195.0	245.0	230.0	310.0
Tot. Hardness (mg/1 $CaCO_3$)	---	---	200.0	290.0
Ca (dissolved)	---	---	73.0mg/1	45.0
Mg (dissolved)	---	---	4.0mg/1	43.0
Tot. Ash Residue	218.0mg/1	302.0	348.0	520.0
Oil & Greases	1.7mg/1	1.7	1.2	---
Phenols	0.003mg/1	0.002	0.004	0.001
Nitrogen (nitrate & nitrite)	0.1mg/1	0.1	0.3	0.5
Nitrogen (diss. NH_3)	0.2mg/1	0.5	0.8	1.2
Tot. Phosphate	0.6mg/1	0.5	0.5	0.7
Sulphate (diss.)	---	---	60.0mg/1	65.0
Chloride (diss.)	---	5.0mg/1	2.0	9.0
Potassium (diss.)	1.1mg/1	1.7	1.0	---
Sodium (diss.)	10.0mg/1	13.0	11.0	---
Iron (diss.)	---	---	LT 0.1	LT 0.1
Surfactants (mg/1)	---	0.2	0.15	LT 0.1

LT denotes "less than" when preceding a number.
* units of organisms/ml.
** units of organisms per 100 ml.
*** units of micromhos/cm.
****denotes Threshold Odor Number.

TABLE B-V

GOVERNMENT DATA FROM SAMPLING AT THE NEVIS GAS PLANT

	Nov.16,1971	Nov.30	Jan.5,1972	Feb.15
DO	14.5mg/1	13.1	1.9	5.0
BOD-5-20	1.0mg/1	0.8	1.0	0.9
Tot. Coliform*	0	0	8	---
E. coli*	0	0	2	---
Standard Plate Count**	20	1	300	---
Temperature (^{o}C)	---	0.0	0.0	0.0
pH	8.4	8.4	7.8	7.6
Spec. Conductance***	---	---	---	520
Turbidity	1 JTU	1	1	1
Odor****	2.0	4.0	4.0	4.0
Tot. Alkalinity (mg/1 $CaCO_3$)	190.0	255.0	240.0	240.0
Tot. Hardness (mg/1 $CaCO_3$)	---	---	285.0	250.0
Ca (dissolved)	---	---	46.0mg/1	41.0
Mg (dissolved)	---	---	41.0mg/1	35.0
Tot. Ash Residue	248.0mg/1	322.0	368.0	380.0
Oil & Greases	2.0mg/1	2.6	1.0	---
Phenols	0.000mg/1	0.001	0.005	LT 0.001
Nitrogen (nitrate & nitrite)	0.2mg/1	0.2	0.3	0.5
Nitrogen (diss. NH_3)	0.2mg/1	0.2	0.8	0.7
Tot. Phosphate	0.1mg/1	0.3	0.5	0.4
Sulphate (diss.)	---	---	60.0mg/1	60.0
Chloride (diss.)	---	7.0mg/1	2.0	8.0
Fluoride (diss.)	---	---	---	0.15mg/1
Potassium (diss.)	1.1mg/1	1.8	2.0	---
Sodium (diss.)	12.0mg/1	16.0	15.0	---
Iron (diss.)	---	---	LT 0.1mg/1	LT 0.1

LT denotes "less than" when preceding a number.
* units of organisms/ml.
** units of organisms per 100 ml.
*** units of micromhos/cm.
****denotes Threshold Odor Number.

TABLE B-VI

GOVERNMENT ANALYSIS FOR HEAVY METALS IN RED DEER RIVER SAMPLES OBTAINED 20 MILES WEST OF BOWDEN

	Jan. 5, 1972	Feb. 15
Cadmium (total)	0.001	LT 0.001
Chromium (total)	0.001	0.021
Cobalt (total)	0.005	0.004
Copper (total)	0.004	0.003
Lead (total)	0.020	0.007
Manganese (total)	0.004	0.003
Mercury (total)	LT 0.0005	LT 0.0005
Nickel (total)	0.006	0.012
Selenium (total)	0.01	LT 0.01
Zinc (total)	0.001	0.012

LT denotes "less than" when preceding a number.
All units are in mg/1.

TABLE B-VII

GOVERNMENT ANALYSIS FOR HEAVY METALS IN RED DEER RIVER SAMPLES OBTAINED FROM THE CITY OF RED DEER WATER TREATMENT PLANT

	Jan. 5, 1972	Feb. 15
Cadmium (total)	0.015	0.002
Chromium (total)	0.025	0.002
Cobalt (total)	0.007	0.005
Copper (total)	0.047	0.018
Lead (total)	---	0.019
Manganese (total)	0.028	0.012
Mercury (total)	LT 0.0005	LT 0.0005
Nickel (total)	0.025	0.012
Selenium (total)	0.01	LT 0.01
Zinc (total)	0.008	0.086

LT denotes "less than" when preceding a number.
All units are in mg/1.

TABLE B-VIII

GOVERNMENT ANALYSIS FOR HEAVY METALS IN RED DEER RIVER SAMPLES OBTAINED AT THE JOFFRE BRIDGE

	Jan. 5, 1972	Feb. 15
Cadmium (total)	0.001	LT 0.001
Chromium (total)	0.002	0.001
Cobalt (total)	0.005	0.005
Copper (total)	0.005	0.002
Lead (total)	0.033	0.014
Manganese (total)	0.007	0.016
Mercury (total)	LT 0.0005	LT 0.0005
Nickel (total)	0.009	0.008
Selenium (total)	0.01	LT 0.01
Zinc (total)	0.001	0.068

LT denotes "less than" when preceding a number.
All units are in mg/1.

TABLE B-IX

GOVERNMENT ANALYSIS FOR HEAVY METALS IN RED DEER RIVER SAMPLES OBTAINED AT THE NEVIS GAS PLANT

	Jan. 5, 1972	Feb. 15
Cadmium (total)	0.001	LT 0.001
Chromium (total)	0.002	0.001
Cobalt (total)	0.005	0.005
Copper (total)	0.006	0.005
Lead (total)	0.087	0.014
Manganese (total)	0.025	0.034
Mercury (total)	LT 0.0005	LT 0.0005
Nickel (total)	0.008	0.006
Selenium (total)	0.01	LT 0.01
Zinc (total)	0.004	0.058

LT denotes "less than" when preceding a number.
All units are in mg/1.

APPENDIX C

DAILY DISCHARGES OF THE RED DEER RIVER

AT THE CITY OF RED DEER

(DATA PROVIDED BY THE WATER RESOURCES DIVISION

OF THE DEPARTMENT OF THE ENVIRONMENT

OF THE PROVINCE OF ALBERTA)

TABLE C-I

DAILY DISCHARGES OF THE RED DEER RIVER

AT THE CITY OF RED DEER

DURING JANUARY TO APRIL, 1971

Day	Jan.		Feb.		Mar.		Apr.	
1	306cfs	B	348cfs	B	300cfs	B	404cfs	B
2	306	B	348	B	300	B	404	B
3	306	B	348	B	300	B	412	B
4	306	B	348	B	300	B	420	B
5	306	B	348	B	300	B	428	B
6	306	B	342	B	306	B	438	B
7	300	B	342	B	306	B	445	B
8	300	B	336	B	306	B	2860	B
9	300	B	330	B	312	B	5300	
10	300	B	324	B	310	B	6420	
11	306	B	324	B	310	B	5730	
12	306	B	318	B	317	B	4660	
13	306	B	318	B	317	B	4660	
14	306	B	318	B	324	B	7540	
15	306	B	318	B	324	B	11600	
16	306	B	312	B	324	B	11500	
17	306	B	312	B	331	B	10200	
18	312	B	312	B	331	B	8740	
19	312	B	306	B	338	B	8070	
20	312	B	306	B	338	B	8160	
21	312	B	306	B	345	B	8230	
22	312	B	306	B	345	B	8150	
23	318	B	306	B	352	B	7370	
24	320	B	306	B	352	B	6550	
25	324	B	306	B	359	B	5840	
26	330	B	306	B	359	B	5460	
27	336	B	306	B	366	B	4510	
28	336	B	306	B	373	B	3640	
29	342	B			380	B	3030	
30	342	B			388	B	2480	
31	348	B			396	B		
Mean	314		322		333		5130	
Maximum	348		348		396		11600	
Minimum	300		306		300		404	

B denotes ice cover.
Data is from Federal Hydrographic records.

TABLE C-II

DAILY DISCHARGES OF THE RED DEER RIVER

AT THE CITY OF RED DEER

DURING MAY TO AUGUST, 1971

Day	May	June	July	August
1	2280cfs	2810cfs	2260cfs	1960cfs
2	2140	2490	2160	1910
3	2030	2790	2150	1870
4	2000	3200	2050	1830
5	1980	3590	1870	1770
6	1940	5640	1800	1690
7	1840	9960	1880	1650
8	1700	9390	2010	1680
9	1620	9430	2210	1630
10	1600	7770	2460	1620
11	1580	6130	2710	1610
12	1520	5470	3270	1550
13	1560	4970	3360	1520
14	1910	4670	3300	1520
15	1930	4320	3100	1460
16	1670	3780	2860	1390
17	1550	3380	2580	1340
18	1490	3170	2380	1290
19	1420	3200	2220	1220
20	1370	3500	2220	1150
21	1400	3590	2250	1120
22	1750	3410	2260	1150
23	2110	3530	2340	1240
24	2180	4120	2330	1210
25	2520	4140	2380	1100
26	3110	3600	2440	1040
27	3240	3210	2660	1070
28	3370	2800	2800	1080
29	3190	2540	2640	1100
30	2860	2340	2370	1110
31	2920		2080	
Mean	2060	4430	2430	1420
Maximum	3370	9960	3360	1960
Minimum	1370	2340	1800	1040

Data is from Federal Hydrographic records.

TABLE C-III

DAILY DISCHARGES OF THE RED DEER RIVER

AT THE CITY OF RED DEER

DURING SEPTEMBER TO DECEMBER, 1971

Day	Sept.	Oct.		Nov.		Dec.	
1	1150cfs	753cfs		548cfs	B	261cfs	B
2	1150	734		540	B	247	B
3	1080	712		524	B	240	B
4	977	697		524	B	228	B
5	914	690		532	B	222	B
6	848	673		532	B	198	B
7	847	665		540	B	192	B
8	927	643		548	B	170	B
9	913	648		564	B	150	B
10	851	646		572	B	140	B
11	857	639		572	B	130	B
12	867	639		572	B	120	B
13	883	645		572	B	98	B
14	870	720		564	B	98	B
15	813	773		564	B	102	B
16	784	742		548	B	110	B
17	764	689		532	B	122	B
18	741	640		524	B	142	B
19	752	655		500	B	160	B
20	790	660		484	B	175	B
21	811	633		460	B	180	B
22	775	632		428	B	180	B
23	737	610		380	B	180	B
24	710	616		333	B	180	B
25	704	615		317	B	180	B
26	695	611		310	B	180	B
27	720	542		303	B	180	B
28	740	669		289	B	190	B
29	736	620	B	282	B	190	B
30	743	572	B	268	B	190	B
31		556	B			190	B
Mean	838	656		474		172	
Maximum	1150	773		572		261	
Minimum	695	542		268		98	

B denotes ice cover.
Data is from Federal Hydrographic records.

TABLE C-IV

DAILY DISCHARGES OF THE RED DEER RIVER

AT THE CITY OF RED DEER

DURING JANUARY TO MARCH, 1972

	January		February		March	
1	150cfs	B	200cfs	B	165cfs	B
2	150	B	200	B	145	B
3	175	B	200	B	125	B
4	175	B	180	B	100	B
5	180	B	142	B	85	B
6	170	B	200	B	70	B
7	170	B	180	B	90	B
8	170	B	200	B	120	B
9	170	B	190	B	138	B
10	170	B	205	B	150	B
11	155	B	200	B	200	B
12	180	B	200	B	205	B
13	170	B	210	B	245	B
14	180	B	200	B	245	B
15	220	B	220	B	250	B
16	225	B	205	B	250	B
17	195	B	155	B	250	B
18	215	B	165	B	250	B
19	200	B	190	B	300	B
20	205	B	225	B	1500	B
21	210	B	215	B	1000	
22	200	B	235	B	1200	
23	210	B	205	B	1500	
24	205	B	175	B	1700	
25	245	B	200	B	2000	
26	250	B	200	B	2200	
27	245	B	160	B	2500	
28	210	B	200	B	2700	
29	160	B	180	B	3000	
30	200	B			3200	
31	200	B			3300	
Mean	192		194		938	
Maximum	250		235		3300	
Minimum	160		142		70	

B denotes ice cover
Data is from Federal Hydrographic records.

APPENDIX D

DETAILED SEWAGE TREATMENT DATA

PROVIDED BY

THE CITY OF RED DEER

TABLE D-I

BOD AND SUSPENDED SOLIDS DATA FOR

RAW INFLUENT AND FINAL EFFLUENT AT THE

CITY OF RED DEER SEWAGE TREATMENT PLANT

Date	Raw Influent		Final Effluent	
	BOD-5-20	T.S.S.	BOD-5-20	T.S.S.
Dec. 8, 1971	601mg/1	442mg/1	41mg/1	45mg/1
Dec. 22	1006	666	124	71
Jan. 27, 1972	550	383	145	166
Feb. 2	829	386	193	130
Feb. 9	523	280	126	138
Feb. 16	312	133	100	100
Feb. 23	576	275	94	158
Mar. 1	625	566	122	148
Mar. 8	535	416	111	105
Mar. 15	537	283	75	151
Mar. 22	502	342	57	61
Mar. 29	404	228	59	63

T.S.S. is the Total Suspended Solids.

TABLE D-II

MEAN DAILY SEWAGE FLOWS

AT THE CITY OF RED DEER

DURING THE WINTER OF 1971-72

Date	Sewage Flow
Sept. 28 -- Oct. 5, 1971	2.23 mgd
Oct. 5 -- 12	2.42
Oct. 12 -- 19	2.40
Oct. 19 -- 26	2.43
Oct. 26 -- Nov. 2	2.72
Nov. 2 -- 9	2.53
Nov. 9 -- 16	2.38
Nov. 16 -- 23	2.42
Nov. 23 -- 30	2.27
Nov. 30 -- Dec. 7	2.32
Dec. 7 -- 14	2.36
Dec. 14 -- 21	2.33
Dec. 21 -- 28	2.13
Dec. 28 -- Jan. 4, 1972	2.24
Jan. 4 -- 11	2.41
Jan. 11 -- 18	2.30
Jan. 18 -- 25	2.39
Jan. 25 -- Feb. 1	2.56
Feb. 1 -- 8	2.56
Feb. 8 -- 15	2.59
Feb. 15 -- 22	2.62
Feb. 22 -- 29	2.54
Feb. 29 -- Mar. 7	2.57
Mar. 7 -- 14	2.68
Mar. 14 - 21	2.81

The City of Red Deer obtained the measurements of the sewage flows by using a Parshall flume.

TABLE D-III

DAILY VARIATION OF FLOWS AND DO OF FINAL EFFLUENT AT THE CITY OF RED DEER SEWAGE TREATMENT PLANT

Date	Time	Flow	DO
Feb. 2, 1972	0800hrs	2.0 mgd	0.0 mg/I
	0900	2.2	0.0
	1000	3.3	0.0
	1100	4.2	0.0
	1200	4.3	0.0
	1300	3.7	0.0
	1400	4.3	0.0
	1500	3.7	0.0
Feb. 4	0800	2.2	3.3
	0900	2.6	3.7
	1000	3.4	4.0
	1100	4.2	4.6
	1200	4.1	5.2
	1300	4.0	4.5
	1400	3.9	4.6
	1500	3.9	5.0
Feb. 16	0800	2.0	6.0
	0900	2.4	5.8
	1000	3.4	6.1
	1100	4.1	6.0
	1200	4.1	6.0
	1300	3.8	5.9
	1400	3.7	5.9
	1500	3.7	5.8
Feb. 23	0800	1.7	7.0
	0900	1.9	6.9
	1000	3.0	6.8
	1100	3.9	7.3
	1200	4.0	7.2
	1300	3.9	6.0
	1400	3.7	5.4
	1500	3.7	5.5
Mar. 1	0800	1.4	3.2
	0900	1.8	3.3
	1000	3.1	2.8
	1100	3.6	1.6
	1200	3.8	1.4
	1300	3.8	2.4
	1400	3.8	2.4
	1500	3.8	2.3

TABLE D-IV

DAILY VARIATION OF FLOWS AND DO OF FINAL EFFLUENT

AT THE CITY OF RED DEER SEWAGE TREATMENT PLANT

Date	Time	Flow	DO
Mar. 8, 1972	0800hrs	2.0 mgd	4.2 mg/I
	0900	2.2	4.0
	1000	3.5	2.6
	1100	4.1	2.8
	1200	4.3	3.1
	1300	4.0	2.6
	1400	3.9	3.0
	1500	3.9	3.0
Mar. 15	0800	1.6	2.7
	0900	1.9	2.6
	1000	3.0	2.3
	1100	3.8	1.7
	1200	3.8	1.9
	1300	3.8	2.6
	1400	3.9	1.5
	1500	4.1	1.5
Mar. 22	0800	1.7	0.0
	0900	2.6	0.0
	1000	3.6	0.0
	1100	4.3	0.0
	1200	4.2	0.0
	1300	4.1	0.0
	1400	4.0	0.0
	1500	4.0	0.0
Mar. 29	0800	1.6	0.0
	0900	2.2	0.0
	1000	3.5	0.0
	1100	4.3	0.0
	1200	4.1	0.0
	1300	4.0	1.3
	1400	3.9	1.1
	1500	3.9	1.0